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Archaeological Investigations of Early Glass Production at Igbo-Olokun, Ile-Ife (Nigeria)

by

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ABSTRACT

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Between 2010 and 2012, archaeological excavations at Igbo Olokun in the town of Ile-Ife in southwestern Nigeria recovered over 12,000 glass beads as well as hundreds of glass-encrusted crucible fragments, other glass production debris, and pottery. The sacred grove of Igbo Olokun is best known as the location where Classic period (12^{th}-15^{th} century A.D.) terracotta and copper alloy sculptures were found in the early 20^{th} century. Although common on the surface at the site, the glass materials at Igbo Olokun have, to date, received relatively cursory attention. This dissertation describes the deposits and the recovered materials, establishing a framework for future comparative and analytic research on glass beads, bead production debris, and ceramics. Using chemical and physical analyses of the glass beads and glass production debris, the thesis explores competing hypotheses of the production of glass beads: were beads made from glass produced in Ife, or were they made of imported, remelted glass?

The analysis reported here includes optical microscopic examination of the glass-encrusted crucibles in cross-section, as well as compositional analysis of glass beads, crucibles and other production materials using LA-ICP-MS, SEM/EDS, and SEM. These procedures confirm the prevalence of glass that is very high in alumina content. High Lime High Alumina (HLHA) glass has previously been identified at Igbo Olokun on samples of uncertain provenience. The recently excavated beads confirm that HLHA glass is very common, but Low Lime High Alumina (LLHA) glass is also present. These results expand on previous work that suggests high alumina glass represents a glassmaking tradition unique to West Africa, and possibly unique to southern Nigeria. Additionally, the excavated assemblage includes a full range of production debris including glass droplets, wasters, and cullet suggesting the different stages in glass bead

production from initial drawing of glass canes to heat treatment of snapped bead ends. The results of the bead classification and compositional studies have expanded the limited comparative database for distribution studies of various glass recipes and bead types in West Africa.

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Chapter 1

INTRODUCTION AND OVERVIEW

This dissertation describes the results of archaeological excavations in Igbo Olokun, a sacred grove that is part of the Yoruba spiritual capital of Ile-Ife, southwest Nigeria (Fig. 1.1). Igbo Olokun has attracted considerable archaeological attention, beginning over a century ago with the Leo Frobenius expedition, owing to the finds of copper alloy and terracotta Ife heads as well as glass beads and crucibles crusted with melted glass. The Ife heads, both in cast brass and terracotta, subsequently dominated investigations in Ile-Ife, creating a particular focus on their chronology and relationship with other notable aspects of material culture, such as potsherd pavements. The effect was a reduction of the archaeology of Ile-Ife to an art historical perspective that focused on the stylistic and historical antecedents of the artwork. This sculpture-centered approach has overshadowed the dynamics of the material culture in early Ife in relation to archaeological understanding of the lifeways of its inhabitants. The majority of previous archaeological excavations in Ile-Ife have been reported incompletely, if at all.

As a departure from the "art-centric" nature of Ile-Ife archaeology, this dissertation provides detailed data on all major find categories and contexts from excavations undertaken in Igbo-Olokun and a second site outside of Ile-Ife, Igbo-Rudi, in 2010 and 2011 (Babalola 2011). I undertook more excavations in Igbo-Olokun in 2011 and 2012, with the aim of collecting data to build a reliable database for future investigations in Ile Ife and in Yorubaland more broadly. Most of the deposits revealed by this research appear to be mixed deposits of waste materials associated with glass bead

Production; nevertheless, the data generated reveal much about the production process, composition of materials such as glass beads and crucibles, and the chronology of the sites.

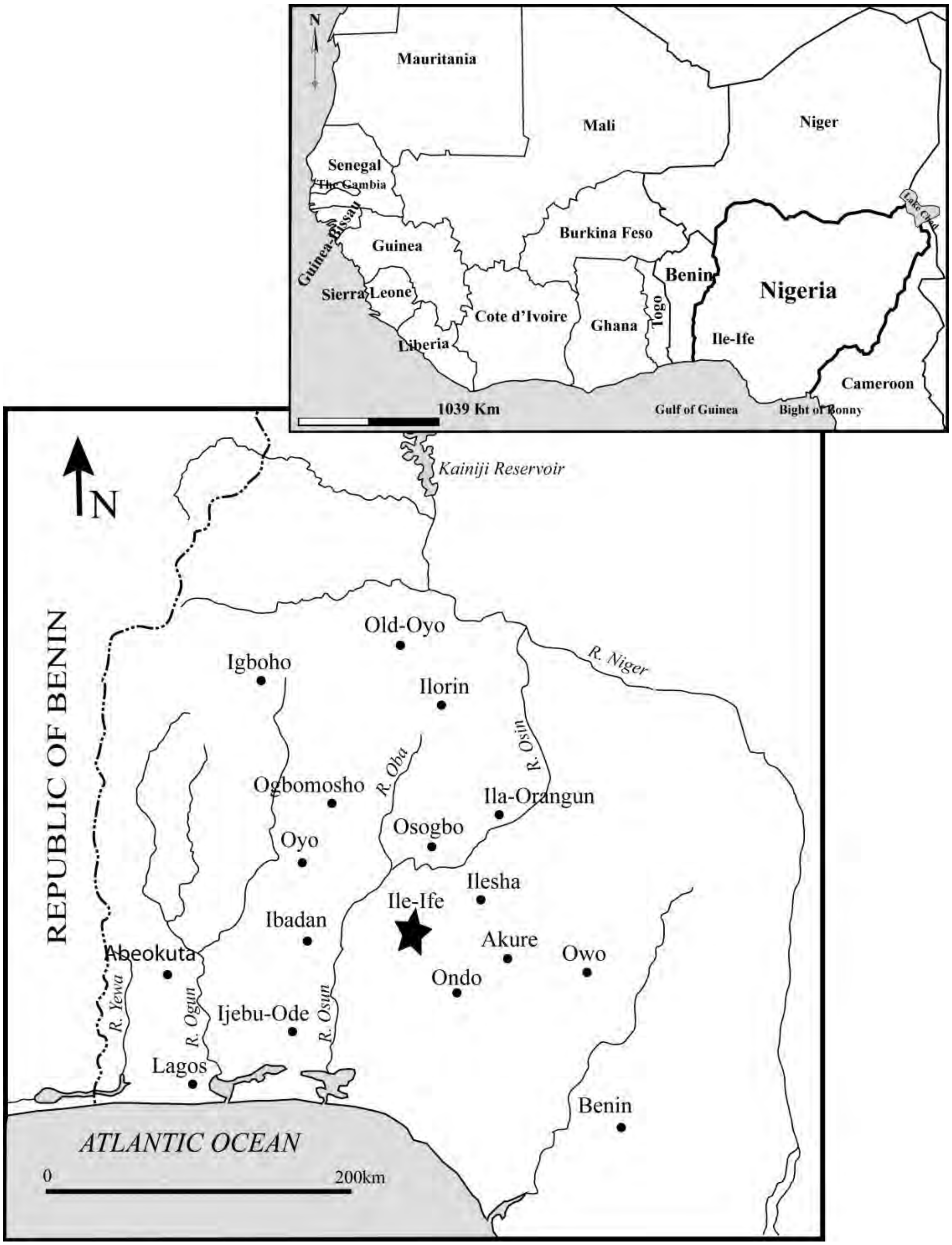

Figure 1.1: Map showing Ile-Ife in southwest Nigeria and other places mention in the text.

The analysis and assessment of the data from excavations at Igbo Olokun addresses two issues that are pertinent to our understanding of early glass production in sub-Saharan Africa. First, I seek to challenge the conventional wisdom that early primary glass production centers were restricted to the Middle East, Southeast Asia, and the Mediterranean (Davison 1972). This idea has been sustained for so long due to lack of archaeological data from reliable contexts in Sub-Saharan Africa. The data from Igbo-Olokun suggest that all production stages of bead-making occurred locally, from the production of glass, to the drawing of beads, to their final shaping. This evidence will challenge theories that glass production in Sub-Saharan Africa was only from remelted, imported glass (e.g. Davison 1972; Willett 1977), and that most finished beads were acquired through intercontinental trade (e.g. Wood 2011). It supports and expands the argument for local production offered by Lankton *et al*.(2006). Second, I situate the data from Igbo-Olokun glass among other important early West African communities such as Gao in Mali and Igbo Ukwu in southern Nigeria, in order to examine both inter-regional and regional interaction and trade networks.

Archaeological and historical sources provide robust evidence on regional and long-distance trade networks in West Africa (e.g. Insoll 2000; Insoll and Shaw 1997; Sutton 2001; Nixon 2007, 2009; Levtzion and Hopkins 1981). By the 8^{th-} to 9th centuries A.D. societies in sahelian West Africa were actively trading salt, copper, gold, and glass with Berbers and Arabs from North Africa. Soon thereafter, these trade networks had expanded to more West African communities. There were also increased producers/production of traded items and complex distribution network across West Africa. A number of Arab authors document glass beads as one of the major trade items (Levtzion and Hopkins 1981). The place and involvement of Ile-Ife, especially the trade in Igbo-Olokun type of glass beads, in these complex trade networks in early West Africa are pivotal to this study.

The work described here is built upon the important work of James Lankton, Akin Ige, and Thilo Rehren (2006) who were the first to argue for local primary glass production in sub-Saharan Africa. In making this case, they have raised three important issues. First, they argue that the high lime high alumina (HLHA) glass at Ile-Ife is evidence for a glassmaking tradition unique to West Africa, and possibly unique to southern Nigeria and to the Yoruba culture (Lankton et al 2006: 111), dating to the "florescence" era in Ife (12^{th}–15^{th} centuries A.D.). The second issue centers on understanding the functions of the numerous crucibles that have been recovered from archaeological sites in Ile-Ife. This is linked to the question of whether or not glass was produced, rather than merely remelted, in the crucibles. The third issue relates to understanding how Ile-Ife glass beads were produced. Although the authors suggest that the production of the small drawn glass beads is a mark of a well-organized and sophisticated craft, the nature of the production process remained unremarked (Lankton *et al* 2006:124). The bulk of their argument is devoted to the first issue while the others were left largely unanswered. In this dissertation, I provide archaeological evidence that is consistent with their hypothesis of local primary glass production in Ile-Ife, but also reconstructs the historical and technical processes involved in the production and distribution of glass beads in Igbo Olokun.

To evaluate the historical processes that created the archaeological data recovered from Igbo Olokun, we need to understand the historical, geographical, and archaeological context within which Ile-Ife was situated. Chapter 2 provides background information on the history of Igbo-Olokun within the context of Ile-Ife. To do this, I discuss the significance of Ile-Ife in Yoruba historiography, as well as a description of the town's geographical and cultural landscape with special attention to situating Igbo-Olokun within Ile-Ife's "ritualscape." The pioneering work of Samuel Johnson (2012 [1921]) on Yoruba history and the recent compendium of Yoruba historiography from the earliest time to recent periods by Akintoye (2010) are central to this discussion. In addition, the idea of Ile-Ife as a ritual headquarters of the Yoruba people, dotted with numerous shrines and temples and inhabited by hundreds of gods and deities, is prominent in the literature (e.g. Frobenius 1968 [1913]; Murray 1948, Fabunmi 1969; Garlake 1974, 1977; Adediran and Arifalo 1992; Olupona 2011). I further discuss the development of archaeology of Ile-Ife from an endeavor focused on rescue operations (that is, archaeological projects resulting from chance discovery and lacking research design) to that dominated by systematic research projects directed at answering specific research questions. This later phase of archaeology of Ile-Ife has generated a number of chronological sequences for the occupation of early Ife. These periodizations are critically reviewed in the latter part of Chapter 2.

Investigating production in archaeological studies involves examination of the type of production (primary or secondary), the scale of production (household or industrial), production techniques, and process of production (Costin 2001, as well as the production mode (partial or complete) and recipe of production, in the case of glass. Since studies on ancient glass production have focused on materials from the Middle East, Mediterranean, Southeast Asia, and parts of Europe, Chapter 3 provides a global survey of studies on ancient glass production. In so doing, I first briefly consider the chronology of glass and its spread across the globe. I then look at the processes of, and recipes for, glass production. Both the process and recipe leave their signature in the chemical composition of the product, and thus I discuss various chemical compositional groups known for archaeological glass around the globe in connection to the possible place of origin of the glass. Considering the importance of Lankton *et al's* (2006) work as the pioneering effort at investigating local glass production in sub-Saharan Africa, I present a thorough review of their work in the last section of Chapter 3.

Chapter 4 discusses the archaeological excavations carried out in Igbo Olokun between 2010 and 2012. It includes data from preliminary test excavations carried out in 2010 in Igbo-Olokun and Igbo-Rudi (a refuse mound site located several kilometers southeast of Igbo Olokun). This chapter also discusses the challenges encountered and the methods employed for the excavations, as well as a unit-by-unit description of the excavated deposits. This chapter details the stratigraphic sequence in all the excavated units, and also examines the relationship among the units. Finally, Chapter 4 presents a discussion on site chronology, describing the results of ^{14}C and TL/OSL dating of charcoal and crucible samples recovered from the excavations.

Chapter 5 presents a detailed analysis of the excavated pottery. This chapter is particularly important because of our limited knowledge of Ile-Ife pottery. Garlake's (1977) important work on pottery is currently the only thorough study on material from Ile-Ife. Thus, this chapter builds on Garlake's work, significantly expanding the analysis. The chapter lays out the procedures of recovery and recording of pottery, describes the variables recorded on the sherds. These data are used to present an overview discussion of the assemblage and compare it to other assemblages from Ile-Ife pottery as well as other sites within the region and across Nigeria. This comparison helps to examine the spread of Ife influence, in term of the presence of Ife materials, in regions of Nigeria and West Africa.

Chapter 6 provides a detailed description of the small finds from excavations. These finds include ceramics other then pottery, burned clay, stones artifacts, iron objects and slag, animal bones, and cowry shells. Rather than treating these materials as less significant, this chapter describes them first as classes of finds in Igbo Olokun, and second, situates them within the larger historical context in early Ile-Ife as well as Yorubaland on a broader scale.

Previous excavations in Ile-Ife have demonstrated that glass beads are ubiquitous materials that can provide information on the prevailing technology, political economy, and trade networks in early Ile-Ife (Davison 1972; Willett 1967, 1977; Garlake 1974, 1977; Eluyemi 1978, 1987; Horton 1979; Adeduntan 1985; Ogundiran 2002a). As such, Chapter 7 presents the results of the analysis of the glass beads excavated from Igbo-Olokun. The chapter discusses the results of the analysis in two major parts. First is the classification of the thousands of glass beads recovered from the excavations, focusing on color, dichroism, shape, size, end treatment, surface condition, and technique of production. The second part is devoted to the results of the chemical compositional analysis of several glass bead samples. While the former allows stylistic description, the latter provides information on the recipes and chemical compositions of the materials. The compositional analysis reveals major, minor, and trace elements, which enables a comparative discussion of Igbo-Olokun glass beads with those from elsewhere within Ile-Ife (Davison 1972; Lankton *et al.* 2006), and outlier settlements from the 12th to 19th centuries (Ige *et al* under review). The chapter also considers Igbo-Olokun glass beads in their larger regional and West Africa context.

Chapter 8 discusses the results of the analysis of production-related materials from Igbo Olokun such as crucibles, glass wasters, ceramic cylinders, and vitrified production debris. This chapter first describes each of the material classes and their occurrence and distribution in all the excavated units. It then presents the results of chemical compositional analysis carried out on selected samples of each of the production-related materials using Scanning Electron Microscope (SEM) with Energy Dispersive System (EDS) technique. The main concern of the compositional analysis of the various production materials was to determine their chemical context and to examine the relationship among the different materials, to explore the evidence of their use in high temperature environments.

For decades, the crucibles from archaeological sites in Ile-Ife have been viewed as evidence for the remelting of imported glass (Frobenius 1968; Davison 1972; Willett 1967, 2004; DeCorse 2001). The reason this view has lingered for so long is, in part, because of the lack of detailed study of the composition of the materials. Thus, studies on crucibles were based entirely on the description of their physical characteristics. Although Lankton *et al* (2006) were the first to chemically analyze both the fabric and inner glass of Ile-Ife crucibles, they did not offer an interpretation of how the material was used in glass production. Understanding the function of the crucible is connected to a fuller knowledge of its technical attributes as there is a "strong relationship between the functional requirements and technical attributes of crucibles" (Bayley and Rehren 2007: 46). In Chapter 8, I combine both the technical and functional attributes of the crucibles from Igbo-Olokun to offer an interpretation of their use. The data generated from careful recording of the excavated crucibles and the data from both microscopic and chemical analysis of the fabric and inner glass are very helpful in this regard. One question that emerges is the relationship between the crucibles and other production debris: if the crucibles were used for glass production, is there a relationship between the crucible glass, glass wastes, and the glass beads recovered from Igbo-Olokun? Although evidence of primary glass production does not necessarily translate to glass working on the same site, as I will discuss in Chapter 8, Igbo-Olokun demonstrates that glass working was carried out locally at the site with the possibility of primary glass production nearby. Finally, Chapter 8 compares the results from the analysis of crucibles to those other production-related materials to make inferences on the raw materials available for production as well as the types of production that took place at the site.

Chapter 9 provides conclusions based upon the data described in previous chapters. In this chapter, I return to the research questions, which include investigating the technique and process of glass production, establishing a chronology for the production, and considering whether or not Igbo-Olokun may have been a primary glass production center.

Based on the result of the various analyses and comparison with existing literature on the possible source of raw material for Ife glass (e.g. Lankton *et al* 2006; Freestone 2006, Ige *et al* Under Review), I lay out in Chapter 9 the possible local source for some of the raw materials for Igbo-Olokun glass, and I conclude that Lankton *et al*.'s (2006) argument for local, primary glass production is fully supported by the data from Igbo-Olokun. This craft production occurred on an industrial rather than household scale and spanned over several centuries. However, this chapter argues that unlike the large scale production of raw glass in the Middle East, which was meant for export, the glass production at Igbo-Olokun or its environs was intended for immediate local use from which glass objects, especially beads, were fabricated. These glass beads were then later widely distributed through regional and long distance trade and exchange. Finally, Chapter 9 highlights various stages involved in the local production of glass beads and presents a discussion on the evidence for chronology.

In summary, this dissertation reports on an intensive and comprehensive study of the glass beads and glass production debris excavated from Igbo Olokun. It seeks to answer the following questions: How diverse are the recipes and potential source areas among the glass samples recovered? Is there evidence for primary production of glass from raw materials and primary glass bead production? If so, what were the production techniques and processes? Were the crucibles used for melting glass batch or remelting of imported glass? What was the scale and chronology of production activities? How far were glass beads from Igbo-Olokun traded (locally, regionally, and in long-distance trade) in West Africa?

So far I have discussed the rationale for the archaeological investigation of glass production at Igbo-Olokun and overview of each chapter in this dissertation. I now turn to Chapter 2 where I discuss the historical significance, cultural landscape, and physical features of Igbo-Olokun within a broader context of Ile-Ife. Prior archaeology in and periodization of Ile-Ife prehistory are also discussed.

Chapter 2
ILE-IFE IN THE CONTEXT OF THE ARCHAEOLOGY OF YORUBALAND

Introduction

This chapter gives background information on Ile-Ife, as well as the site of this research project, Igbo Olokun. It examines the conventional historical narratives about Ile-Ife, focusing on the significance of the town in the genesis of Yoruba traditions and the role of the *Ooni,* the traditional ruler of Ile-Ife. As will be discussed in detail, the political structure in Ile-Ife is conceptualized by the Yoruba as a divine kingship system, meaning that the role of the Ooni is equivalent to that of the god. The geography of Ile-Ife will be discussed in depth, with particular attention paid to the environment and its effect on early occupants. The effects of urban growth on the sacred groves throughout the city and the known archaeological sites are also discussed in depth. I then briefly discuss Ile-Ife in historical context with a focus on the state of scholarship concerning Ile-Ife prehistory and the contributions of historical sources and archaeology to understanding early Ile-Ife's history. Finally, I describe prior archaeological investigations in Ile-Ife. I provide a critical assessment of these previous works and explore the way they have enhanced an understanding of the cultural traditions, chronologies, and periodization in early Ile-Ife.

Ile-Ife in Yoruba historical tradition

Ile-Ife, often translated as "spreading of the earth" or a "wide and original home," holds a significant place in Yoruba history. The origin of Ife-Ife is inextricably connected to that of the origin of the Yoruba people. One version of the Yoruba origin history states that *Olodumare*, the supreme God, sent *Oduduwa*,[1] the acclaimed progenitor of the Yoruba, from heaven to create the earth. While on this mission, the oral tradition indicates that Oduduwa first created Ile-Ife. This narrative shows that Ile-Ife is bound up with the origins of the Yoruba people not only in history and theory, but also in myth and legend, making Ile-Ife an obvious starting point for the investigation of Yoruba origins and history.

The pioneering work of Reverend Samuel Johnson (1921)—a Christian missionary and son of Yoruba freed slave—was the first full-length history of the Yoruba. In his account of Yoruba history, Rev. Johnson (1921[2012]) claims that the Yoruba originated in the Middle East, through the lineage of Lamurudu, the King of Mecca. According to Johnson, Oduduwa was the son of Lumurudu who, after he had given in to idolatry, escaped with his children and forces to Ile-Ife. Johnson's claim of the immigrant-founding lineage in Ile-Ife was popular among scholars of the Yoruba in early through mid-20th century (e.g. Talbolt 1926; Lucas 1948; Jeffrey 1958). Over the years, historians of the Yoruba have challenged Johnson's account, arguing that Oduduwa and his kin met a pre-existing group at Ile-Ife (e.g. Olomola 1992; Smith 1988). These scholars argue that when Oduduwa arrived at Ile-Ife, he met with obstacles leading to struggle and turmoil between Oduduwa's followers and the pre-existing group. Akinjogbin (1992) presents a somewhat contrary view on the historical origin of Oduduwa. Rather than being a leader of an immigrant group, Akinjogbin (1992) argues that Oduduwa was part of a preexisting group. Whether Oduduwa was an immigrant or part of an existing group his ascension to power was characterized with chaos and political turmoil. During the battle for political supremacy, Oduduwa's group gained the upper hand and took control of political institutions; Oduduwa thus became a formidable political figure and founder of the first Ile-Ife dynasty.

There are two things that need to be considered in these versions of the origin of the Yoruba. First, Ile-Ife appears to be at the center of Yoruban origin myths and to be generally considered the spiritual birthplace of the Yoruba. As Akintoye (2010: 2)

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[1] There is a version of the myth states that Olodumare first sent Obatala – arch-deity, on the mission. Along the way Obatala got drunk with palm-wine, thus he could not fulfill the mission. Olodumare then commissioned Oduduwa to take over the mission.
Oduduwa succeeded in the mission and became the farther of the Yoruba. As a result many historians credited Oduduwa with the creation of Ile-Ife, and described *Obatala* as political opponent of *Oduduwa*.

argues, the constant reference to the same location in the Yoruba myth of origin may also legitimize the antiquity of the Yoruba in their present location. In addition, several scholars have suggested that the Yoruba would have originated from an area around the Niger-Benue confluence (Atanda 1993:100-101; Adetugbo, 1977:203; Obayemi 1976) dating as far back as ca. 2000-1000 BC (Atanda 1980:14). Historical documents have recorded several accounts of prominent Yoruba traditional leaders and foreigners in the 19th century on the politico-religious significance of Ile-Ife in history and tradition (Lander and Lander 1832; David Hinderer 1850 in Akinjogin 1992; Akintoye 2010: 1-3).

Second, Oduduwa is often referred to as an important figure in the foundation of Ile-Ife, as well as the establishment of dynastic rule in Yorubaland and other adjacent communities (Johnson 1921: 7-12; Aderemi 1937; Parrinder 1956; Egharevbe 1968; Smith 1988; Akinjogbin 1992a; Akintoye 2010: 87-8). Hence, scholars have raised concern about the personage of Oduduwa. For example, Obayemi (1992) has discussed issues relating to the complicated meaning of Oduduwa along genealogical propositions, Ile-Ife oral history, dynastic preferences, modern socio-culture options, chronological interpretation, and locational or geo-cultural latitudes. However, whatever traditional view one has of Oduduwa and Ile-Ife, many Yoruba people, including scholars, agree that the city occupies a central role in historical traditions, accorded the spiritual headquarter of the Yoruba, and the highest and the most sacred traditional title Ooni. I now turn to briefly discuss the seat of the Ooni of Ile-Ife, the paramount ruler of the city.

Seat of the Ooni

It has been discussed that Ile-Ife is the oldest existing dynasty in Yorubaland that has survived till the present (e.g. Akinjogin 1992b; Adediran 1992). The seat of the Ooni (literally meaning the owner) is a significant symbol of political authority in Ile-Ife and Yoruba political history. Adediran's (1992) historical account of the beginning of the Ife state details the events that culminated in the reorganization of the political system and invention of the Ooni title in early Ile-Ife. While Oduduwa is linked to the emergence of centralized politics in early Ile-Ife, Obalufon (one of the kings of Ile-Ife who reigned sometime in early 2nd millennium AD) "is acknowledged as the initiator of the Ooni title"

(Adediran 1992: 91). It is believed that the Ooni is the most powerful and divine ruler and, as a result, he is sometime referred to as the “god king.”

The *aare* or sacred crown of the Ooni is a significant symbolic representation of the leader’s power. The divine authority of the Ooni is “maintained through the power of the sacred *ase* (a strong miracle force) infusing the aare (sacred crown) that elevates the Ooni to the status of a god” (Olopona 2011: 14). The aare is a metal crown festooned with glass beads that represents political authority and power (Adediran 1992: 84). The idea of a beaded crown as a symbol of political office in Yorubaland originated in Ile-Ife. Since Ile-Ife developed the technology of glass-bead making and perhaps even primary glass manufacture (Chapters 7, 8, and 9), it is not surprising that a beaded crown was consecrated as “sacred.” The Ooni wears the aare once a year during the Olojo festival to invoke blessing upon his people and his land. Scholars have documented the process and procession surrounding the Ooni’s wearing of aare and its significance during the Olojo festival in Ife-Ife (e.g. Bascom 1939; Olupona 2011).

Although the Ooni is the highest and most powerful person in the political hierarchy of Ile-Ife and Yorubaland, he still relies on the chieftaincy to support his office. The Ooni reigns over several kinds of chiefs such as the *Ihare* (civil chiefs), the *Isoro* (propitiator of the gods or the priest chiefs), and the *Omode Owa* (the royal servants or princely youths). The chiefs are required to wear glass beads around their neck, wrists, and ankles as symbol of political and/or religious authority. Chiefs also sew glass beads on their hats (*oro*). But a white beaded hat is only for the Ooni. Adediran (1992: 87) has suggested that the use of glass beads as symbols of political office and the acquisition of oro by many chiefs made glass beads prominent in Ile-Ife markets, which may have been a major contributor to Ile-Ife’s prosperity (Horton 1992). The proliferation of chief-priests in Ile-Ife translates into the presence of numerous religious cults, gods, and sacred ceremonies in which glass beads play a significant role.

Ile-Ife as Center of large number of religious cults

The large number of religious cults at Ile-Ife has been a major point of discussion in literature about the sacred city. Adediran (1992: 58-6) has suggested that the first Ile-Ife dynasty, formed through the coalition of pre-dynastic settlements, brought diverse religious cults together. While some of the cults were already in existence prior to the first dynasty, others were established or strengthened as an "opposition to the new regime" (Adediran 1992: 88). In other words, religious cults were components of the traditional political system in Yorubaland that provide checks and balances to the political system.

As religious cults expanded and grew to prominence in Ile-Ife, the numbers of god/deities also increased. Sources on Yoruba religion have referred to the presence of 201, 401, or even up to 601 gods in Yoruba belief systems. In his recent book, Olupona (2011) describes Ile-Ife as "the city of 201 gods." Two lessons can be learned from the occurrence of numerous gods in Ile-Ife. First is that there is a notion of the multiplicity of gods/deities in the Yoruba religion. Secondly, that the gods are seen as uncountable and infinite. Additionally, the addition of "1" to the more general numbers 200, 400, and 600 to indicate the number of gods/deities is particularly important for understanding the primacy of Ile-Ife in Yoruba tradition. Citing Wande Abimbola, Olupona (2011: 88) explains that the number "1" is "proof of inclusivity [within the] Yoruba religious worldview, which is always willing to add one more deity to the pantheon." More importantly, Olupona (2011: 88) further suggests "the extra deity is most probably the Ooni, who is regarded as part of the pantheon …"

Ile-Ife is believed to house all the Yoruba gods/deities. In fact, when Ile-Ife was sacked in the 19th century by the Modakeke, an Ibadan chief who negotiated peace and return of the Ifes back to their original home argued that "it would never do to let the cradle of the race to remain perpetually in desolation and the ancestral gods not worshipped" (Johnson 1921: 232). This statement suggests that unrest at Ile-Ife could translate to unrest in the rest of the Yoruba region. As a result of Ile-Ife's primacy in the Yoruba worldview, several ritual festivals and ceremonies are held throughout the year in Ile-Ife for different deities. Common among the ritual festivals are the Itapa, Edi, Igare, and Olojo. The festivals usually draw pilgrims and observers from far and wide (Olupona 2011). Since the ritual festivals or ceremonies are performed at shrines, many shrines dot the Ile-Ife landscape. These shrines, as I discuss below, have been the focus of archaeological research in Ile-Ife.

Geographical description of Ile-Ife

The establishment of the Obafemi Awolowo University and the research carried out by the Geology Department there have helped to provide better information on ancient Ile-Ife's environment. The work of L. K. Jeje (1992) is a compendium of the ecology of Ile-Ife. His work forms the basis of my consideration of Ile-Ife geography, combining data from all available sources about Ile-Ife and its surrounding towns and settlements. In the rest of this section I will discuss the geographical features of Ile-Ife with a focus on location and layout, climate, geology and topography, soils, drainage and river channels, and vegetation.

Location and Layout

Ile-Ife is located in southwestern Nigeria, in a region that is generally referred to as central Yorubaland. Some historically important towns and cities surround the city of Ile-Ife, such as Apomu, Ikire, and Iwo to the west; Ilesha to the northeast; Ipetu and Akure to the east; Ede and Osogbo to the north, and Ondo to the south. Covering an area of 1846 km^2, Jeje (1992) defines the boundaries of Ile-Ife by geographical features rather than neighboring town and cities. In the west, Ile-Ife is bound by Shasha River, and in the southeast the Oni River (Jeje 1992:1). These rivers are used as part of the territorial makers by the municipal authority, but they not mentioned as prominently in descriptions of the city's layout.

The Ooni's palace is a significant landmark.. It is the central hub of life in Ile-Ife since all major roads are connected to the palace, in a spoke and wheel pattern (Krapf-Askari 1969: 3). The "roads are usually wide thoroughfares, sometimes 30 feet wide" (Mabogunje (1962: 6). However, the directions of the roads radiating out from the palace, leading to neighboring towns[2] are significant in Yoruba belief. All roads are orientated towards the palace, because of a Yoruban tradition that holds that major roads coincide with the cardinal directions (Obateru 2006). Thus, the east road is associated with Sango (god of thunder), the west, Esu (deity in-charge of divine messages), the north, Obatala (god in-charge of the creation of earth and human), and the south, Ogun (god of iron).

[2] T. A. Akinjogbin (1992) discusses in great detail the outlying towns of Ife. He outlines their historical development, proximity in relation to Ife, and their social, economic, political development.

The very layout of the town recapitulates Yoruban cosmology (Obateru 2006: 223). All these gods and deities have their shrines in the Ile-Ife palace, where they are worshipped.

In front of the palace is a market square. Johnson (1921: 91) has defined the location of the market as “a rule without an exception” in Yoruba city planning. The market is even named *Oja’ba* (meaning the king’s market) due to its proximity to the palace. The streets in Ile-Ife are laid out in rectangular pattern, and are approximately 15 feet wide. In the traditional setting, the streets represent “a quarter consisting of a number of compounds housing members of one or more extended family” (Mabogunje 1962: 6). Several houses in contemporary Ile-Ife still maintain their compound names.

Concentric walls are important features of Ile-Ife’s layout. There were two major walls that encircled the early Ife city: the outer one that enclosed the major residential area of the city, and the inner one also known as the “palace wall.” In the traditional setting, this wall surrounded the settlement areas within which space was shared. For example, the common spaces include the residential/domestic, industrial, and religious/ritual (Ojo 1966; Mabogunje 1968: 97). Ruins of this Ile-Ife wall are still visible in places around the contemporary city. These remains were the objects of archaeological investigations about three decades ago (Willett 1967; Ozanne 1969). An in-depth discussion of the structure and the functions of the walls in the historical reconstruction of past events in Ile-Ife are discussed below.

Climate

Located in a humid tropical environment characterized by high temperature and rainfall, the climate of Ile-Ife and its broader region are mostly dictated by the movement of the Inter-Tropical Convergence Zone (ITCZ). The movement of the ITCZ brings about two main seasons: dry and wet. The dry season is characterized by low rainfall months mostly from November through February. Although Ile-Ife has a mean monthly temperature of between 23°C and 27°C, the temperature gets up to 29°C during the dry season. Ile-Ife has longer wet seasons than dry seasons. The wet or rainy season varies between seven and nine months. During the rainy season Ile-Ife receives a mean monthly rainfall ranges of around 113mm to 206mm, with the highest in July and October (Jeje 1992: 6). Typically, the rainfall comes with severe thunderstorms accompanied by high winds up to 50km/hr and high precipitation. The high precipitation usually causes increase runoff down the hills, which results in erosion in most parts of the city.

Geology and Topography

The geology of Ile-Ife is part of the Precambrian Basement of Nigeria, consisting of various gneisses, schist, and quartzite into which granitic and basic rock intruded (Jeje 1992: 8). The bedrock includes varying outcrops of granites and granite-geissess, as a result of these minerals differing resistance to erosion. Jeje (1992: 10-16) has divided the geologic features of Ile-Ife into three types: the gneiss complex, the granitic rocks, and the basic. Depending on texture, mineral composition, and weathering, the three main groups can be sub-divided into several groups among which are quartz, schists, biotite, pyroxene, andesine, feldspar, and pegmatite etc. The occurrence of feldspar and pegmatite in the geologic component of Ile-Ife is important to this research project because is has been suggested that feldspar may be a raw material used in ancient glass production (Freestone 2006a: 140). These rocks occur in the form of varying outcrops including massive whalebacks, exfoliated domes, flat or convex rock pavement, core-stones, and inselbergs.

The topography of Ile-Ife consists of plains, hills, and ridges. The plains, which contain the bulk of the city, are about 280m above sea level. Hills surround Ile-Ife and stretch to about 8 to 10 miles across; the spread of these hills gives the city a "bowl-like" shape (Ozanne 1969: 32) whereby Ile-Ife is located in the center of the valley of the hills. The elevation of the surrounding hills is approximately 75m to 330m above the plain (Jeje 1992: 16). Seven of the hills immediately surrounding Ile-Ife are Oke[3]-Ora, Oke-Araromi, Oke-Owu, Oke Pao, Oke-Ijugbe, Oke-Onigbin, and Oke-Obagile (Eluyemi 1986: 1). One of these hills, Oke-Ora, is referred to as the place from where Oduduwa descended, according to the tradition of origin of Ile-Ife. Archaeological investigations have been carried out at Oke-Ora in order to determine its antiquity (Agbontaen *et al* 1994), but the occupation of the site appears to have been much more recent than expected.

[3] *Oke* in Yoruba language represents a high elevation. It is often used to describe hills.

Soils

The soils in Ile-Ife are associated with parent rocks. High precipitation and runoff from the surrounding hills have been a major mechanism for soil formation in Ile-Ife. Following Smith and Montgomery (1962) and Adejuwon and Jeje (1975), Jeje (1992) describes the soils in Ile-Ife and its surroundings as made up of granite granules, granitic-gneisses, and pegmatites. Most of the soils of Ile-Ife belong to the Iwo and Egbed typologies. Generally occurring along slopes, Iwo soils are coarse sandy clays, containing gravels and concretions, rich in feldspar and quartz, usually brownish gray or brownish red in color. Occasionally, the soils can be very stony and gravelly, with a remarkably sticky texture of coarse sandy clay, which is derived from colluvial materials (Jeje 1992: 31). Ozanne's (1969) description of Ile-Ife soils in the area around the hill slope seems to fit Jeje's: "the bedrock of most of the area is hornblende gneiss, which disintegrates into a heavy clay which can be very sticky in the rainy season... [there are also] outcrops of quartzite and quartz-mica schist which decay into gravels" (Ozanne 1969: 32). He concludes that the early occupants of Ile-Ife chose the area because the soils were well drained and suitable for cultivation (Ozanne 1969: 32). The second prominent soil association in Ile-Ife, Egbeda, is formed from fine-grained biotite gneisses and schist, which mostly occur on the rolling terrain. The upper 50 cm is generally fine-textured with very clay-filled sand to sandy clay, but the gravel and concretions content increase further down in the deposits. The soil color varies from pale brownish gray to brownish red.

Despite the variation in Ile-Ife soils and their suitability for cultivation, they are poor in the preservation of organic materials. The poor preservative nature of the soils has been a major challenge for Ile-Ife archaeology, as bones do not preserve well and charcoal decays easily in the soil.

Drainage and River Channels

The topography of Ile-Ife favors a network of drainage systems. The major rivers traversing north-south through Ile-Ife are the Owena, Oni, and Shasha. Some of the minor rivers and streams are tributaries to the major rivers. Those rivers are Ogbe, Opa I, Opa II, Oni, Agbara, and Esinmirin, among others. These rivers come from sources up in the north from the Niger River and its tributaries, and flow through the lower slopes and valleys to drain into the Atlantic Ocean. All these rivers and streams have a higher velocity and greater volume during the rainy season and are considerably diminished in volume during the dry season. Of these rivers, only Opa, Agbara, and Esinmirin flow through the "bowl" of Ile-Ife (Eluyemi 1986: 1). Considering the proximity of the Esinmirin River to Igbo Olokun (the main site excavated for this dissertation), it may have played a significant role in the location of the site in this area by the past inhabitants. Proximity to a source of water would have been fundamental to the functioning of an industry that was engaged in high temperature activities.

Vegetation

The vegetation of Ile-Ife is primarily rainforest, which is characterized by tall canopy trees that have a trunk diameter of 1 – 1.5m and height reaching 40m. However, several decades of forest disturbance through farming, lumbering, and other activities have impacted the vegetation significantly and transformed the rainforest into a secondary growth forest. This new vegetation is mostly characterized by thick and impenetrable forest. Creeping vines, tree shrubs, and sometimes large trees and robust palm trees are also typical of the secondary forest (Jeje 1992: 37). The intense cultivation of trees and crops in Ile-Ife has formed a dynamic pattern in the vegetation, and Jeje (1992: 35) has listed thirteen such associations. The dominant cultivated trees include cocoa (Theobroma cacao), kolanut (Cola acuminate and C. nitida), and oil palm (Elaeis guineensis).

Having described the geographical features of Ile-Ife, the next section briefly describes the foundation of the municipal government, and rural and urban settlements in contemporary Ile-Ife. It also discusses urban growth in Ile-Ife in terms of settlement expansion and population increases, and their implications for the natural environment and archaeological sites.

Ile-Ife Today

The period that constitutes contemporary or modern Ile-Ife has been a subject of debate. According to Ozanne (1969: 40), modern Ile-Ife was founded in the 17th century during the reign of Ooni Lajamisan. Willett (1967: 34) is of the opinion that modern Ile-Ife came into existence during the colonial administration when the Yoruba civil war ended in the 19th century and peace returned to the region. Considering the return of peace to Ile-Ife and the socio-economic development that followed during the colonial period, Omosini (1992) has called the period between the late 19th century and the first three decades of the 20th century as "the years of recovery" in Ile-Ife. The city was not administratively important until it became the headquarters of the Ife District and Division under the Oyo Province in the colonial administration (Omosini 1992: 173). Ile-Ife held onto this administrative responsibility until the colonial era ended. Therefore, in this brief section, I consider "Ile-Ife today" to be the period from the colonial era to present. During this period, the city witnessed changes in all sectors, but I will only discuss administrative and demographic changes and urban development and their impacts on the environment and archaeological sites.

After the colonial era ended, administratively, Ile-Ife remained as a division under the Oyo province, which later became Oyo state. In August 1991 new state of Osun was created, and Ile-Ife became one of the major cities in the newly formed state. Of the thirty local government areas in Osun State, Ile-Ife constitutes four of them: Ife Central, Ife East, Ife North, and Ife South. Of the four Ile-Ife local government areas only two (Ife Central and Ife East) are within the city of Ile-Ife , which is a highly-commercialized city with several banks and multinational companies. The other two local government areas consist mostly of satellite rural settlements focused on agriculture. Although the Ile-Ife Museum, the federal office that oversees all the archaeological and historical sites, is located in the city of Ife, its jurisdiction covers both the city and the satellite areas.

There is a reciprocal relationship between the metropolis and the satellite areas. While the rural settlements supply food items to the cities, the cities serve as trading centers for the rural settlements, where the satellite dwellers bring their agricultural produce such as cocoa, kola, plantain, cotton, tubers, and so on for sale. The population size and the metropolitan nature of the Ile-Ife township make it an ideal place for holding markets.

The population of Ile-Ife has increased steadily since the early 20th century. After a peace resolution was reached and Ile-Ife was reoccupied in 1913, its population was about 48,016 (Omosini 1992: 173). By 1963, the population of Ile-Ife had increased to about 376, 718. The last census of 2006 puts the current population of Ile-Ife at 644,373.The work of Ajala and Olayiwola (2013) on land use, land cover, and urban dynamics in Ile-Ife over a period of twenty-one years (1986-2007) has revealed a trend in Ile-Ife urban growth which is alarming to archaeologists. During these years, Ajala and Olayiwola (2013: 48) observed that built-up areas had increased in Ile-Ife from 17.6 km^2 to 79.39 km^2 constituting an approximately 350% change. Ajala and Olayiwola (2013: 48, 51) therefore conclude that this trend of urban growth indicates that cultivated and natural vegetated areas are being converted to built-up areas. This rapid urban development in Ile-Ife has implications for the archaeology of the city, as many archaeological sites are disturbed, looted, and permanently built over. In fact, many archaeological sites were discovered in the process of one or more of these disturbances. I discuss some of the early accidental discoveries in Ile-Ife during construction and mining in greater detail in the later part of this chapter.

Sacred groves/shrines in Ile-Ife

Sacred groves and shrines are common in Ile-Ife. As already mentioned, there are numerous gods and deities in the Ile-Ife pantheon and worship places are created for each of them. While some of the gods/deities are non-human beings, others are human figures that lived in Ile-Ife and were deified after their death. For example, Yoruba gods and deities such as Obatala (god of purity), Olokun (goddess of wealth and prosperity), Oya (goddess of wind and tempest), and Moremi (goddess of bravery) are all historical figures (Adepegba 2008). These deities are assigned sacred shrines or groves where they are venerated by believers. This association of sacred groves and shrines with deities makes groves places where “offerings are made, prayers are said, and people interact with the deities who influence their daily lives” (Schildkrout 2009: 22). After the gods are appeased the devotees expect changes in his/her situation.

Sacred groves represent portions of the forest for the veneration of particular gods or deities. As such, the forests, and every resource within them, becomes sacred and therefore taboo to exploit. Tree and herbs cannot be used, water cannot be drawn, and fish must not be caught in rivers within groves, except for ritual purposes. Additionally, movement is highly restricted in the forest. On most occasions, only priests or ritual processions are allowed. For example, in Yorubaland, the sacred grove is where ritual rites are performed for a new king.

Shrines, however, can be part of a sacred grove or located in a separated area where offerings are made to gods/deities. Shrines are places of worship and sacrifice, furnished with objects and items that symbolize the nature and efficacy of a particular deity. Remnants of the sacrifices offered at the shrines are left at the shrine to decay and accumulate. If the shrine is abandoned, these objects and the sacrificial residue can become archaeological deposits. Thus, sacred groves or shrines in Yorubaland encapsulate long-term dynamic historical process (Sheridan 2009). They may also be considered constructed and ideational meaning that sacred groves and shrines are not natural but rather, are constructed, and can be re-constructed, or deconstructed altogether because they are products of the ideological symbolism embedded in Yoruba belief system.

Sacred sites make up much of the archaeological landscape of Ile-Ife. The proliferation of sacred groves and shrines in Ile-Ife has attracted archaeologists, anthropologists, and historians to sacred places, and prompted them to document the sites and associated ritual practices (e.g. Frobenius, 1968 [1913]; Murray 1948; Fagg 1953; Bascom 1969). Similarly, archaeological efforts have concentrated on sacred groves (e.g. Fagg 1953) and have reported objects, features, and other ritual items that suggest that some of the shrines and temples studied in Ile-Ife date to the 12^{th} – 16^{th} centuries AD (Garlake 1974, 1977; Eyo 1974, 1977). The main site investigated in the present study, Igbo Olokun or 'Olokun grove,' is a good example of a sacred grove that was subject to archaeological excavations over many decades. I will discuss prior archaeological excavations at Igbo Olokun later in this chapter; here I will place Igbo Olokun in historical context.

Igbo Olokun (Olokun grove)

Igbo Olokun is a sacred grove dedicated to Olokun[4]. According to oral traditions, Olokun was one of the wives of an early paramount ruler of Ife-Ile. Although childless, oral tradition and historical memory in Ile-Ife claim that she was the first to manufacture glass beads in Ile-Ife. Her industry is believed to have been established at Igbo Olokun, and her residency at Walode Compound in Ilode, Ile-Ife. Industrious and wealthy, Olokun was reputed to have been the richest woman during her time (Eluyemi 1978: 18). After her demise, she was deified for her wealth and industriousness, making the site of her industry considered sacred.

Literarily, the name *Olokun* means the "owner of the sea." However, scholars of Yoruba studies have interpreted the name in different ways, and often associated it with the ocean, particularly the Atlantic. Frobenius (1913 [1968: 320, 321]) not only interpreted Olokun to be "Sea God," but also argued that the Ife "civilization has its home in the Atlantic Ocean's shore." Although Frobenius' external origin of Ile-Ife's antiquity has been refuted, scholars continue to associate the name, Olokun, with the sea and ocean suggesting a connection with the Atlantic Ocean (e.g., Eluyemi 1987; Schildkrout 2009; Olupona 2011). "Okun" in Yoruba language and culture represents flowing water and is also associated with abundance and wealth. Historical memories in Ile-Ife state that, in the past, the Okun River, which is in close proximity to the Walode compound (an acclaimed resident of Olokun; Eluyemi 1978: 17; Ogunfolakan pers. comm. 2015), was expansive and constantly flowing, even though it is mostly stagnant today. If Olokun resided at Walode then the name may have been taken from the Okun River rather than connected with the Atlantic. Such local interpretations are preferable to external origins theories that have little basis in local histories.

The prowess and significance of Olokun is demonstrated in the construction of shrines in various places within Ile-Ife. One shrine is constructed for Olokun at Walode compound, and another dedicated to her at Wasin Compound in Ilare. Annual festivals

[4] Although Olokun is generally considered a female figure, there has been some debate over the sex of the deity. Fagg and Underwood (1949) have challenged the conventional wisdom among Yoruba scholars by claiming that Olokun is a male. Also Frobenius (1968: 102, 320, 321) often refers to Olokun as a god rather then a goddess, implying male personage.

are held at these shrines where sacrifices are offered to Olokun. Frobenius (1968: 306) listed sacrifice items that include "black bulls, black buck-goats, black chickens, black cloth, dark-colored doves." It is striking that all the sacrifice items for the goddess, Olokun, are black or dark color, yet no mention is made in the literature and oral tradition as to why it is so. There was also likely a shrine within Olokun grove, although the location of this shrine is not known today; Eluyemi (1987: 197) has suggested that the "Ojubo (shrine) was located within the center of the grove." Unfortunately it is impossible to determine where the center of the grove is today.

The cult of Olokun is commanded by the priestesses who are given the title of *"Yeye M'okun"* by the Ooni. Other members must be initiated into the cult; these members usually include bead makers and sellers. According to discussions with informants in Ile-Ife, it seems the festival is dying out. The position of Yeye M'okun had been vacant for several years before the current priestess was assigned, and thus there had been no one to organize the festival. However, there is still an annual ritual 'bead hunt' celebrated in the area by the members of Olokun cult. During this event, members will congregate at a known location within the city. After prayers have been offered to Olokun, they set out and rally around the city, singing "Lokun lokun gbe 'ra nle, Oba erupe gbe 'ra nle" (Olokun arise from the ground, king of the soil arise). We were told by the priestess that the more they sing and dance, the more beads will appear on the surface of the ground for them to collect. Since this ritual bead hunt is held during the rainy season, archaeologists must consider two things: first, that the beads would have been exposed or washed down by erosion; and second that the act of collecting archaeological material is still ongoing in Ile-Ife. These issues are therefore relevant for our understanding of the condition of the site.

The Sites: Location, description and condition

This study focuses on two sites, Igbo Olokun and Igbo-Rudi (Fig 2.1). Igbo Olokun is located in the heart of Ile-Ife, while Igbo-Rudi is on the outskirts of the city; both are located within Ile-Ife territory. In this section, I will describe the location and the condition of the sites. Igbo Olokun has been investigated previously and is recognized as a glass bead industrial site; the site is located in the north of Ile-Ife, close to the Ife city wall. The site is situated within the Irebami area of Ile-Ife on Lane 7, approximately one kilometer southwest of Ajegunle Bus Stop on Fajuyi Road. Although the exact size of the site is unknown, a number of scholars have attempted to define its boundaries (Willett 1967: 15). Frobenius did not provide a site size, but describes the site as a "vast forest" (1968: 305). Narrating the legend he was told in Ile-Ife, Frobenius describes the features that border the site: "…Illu-Olokun [the town of Olokun]…to the north of Ilife [Ife]…was surrounded by a lake to the south and river on the north…" (1968: 306). This description allows us to approximate the site size by following the rivers mentioned in the legend. The site is bordered by the Esinmirin River to the north and east; there is, however, no lake or river to the south. The absence of water as the boundary to the south does not, however, dismiss the significance of the site location near a water source.

Eluyemi (1987:197) has estimated the total area of Igbo Olokun to be over ten acres, starting at about "half a kilometer from Fajuyi Road and stretching almost to the Esinmirin stream on Ilesha Road." Similarly, Willett (2004: Chapter 1.2) suggests that Igbo Olokun "covers an area of three quarter of a mile by half a mile (i.e. 2 by 0.8km)" but does not describe the boundaries. In addition, during our preliminary work at the site, Dr. Adisa Ogunfolakan, a local archaeologist, was of the opinion that the western limit of Igbo Olokun extends to Ooni Ilare Street with a road and Ogboku stream as the western boundary. This western end of the site was checked through excavations, the results of which are presented below. Drawing together all these observations, as well as evidence from surface materials such as potsherd pavements, I have created a hypothetical set of boundaries for the original site. In this reconstruction, the site area is estimated to be more than 268 hectares. (Fig 2.2).

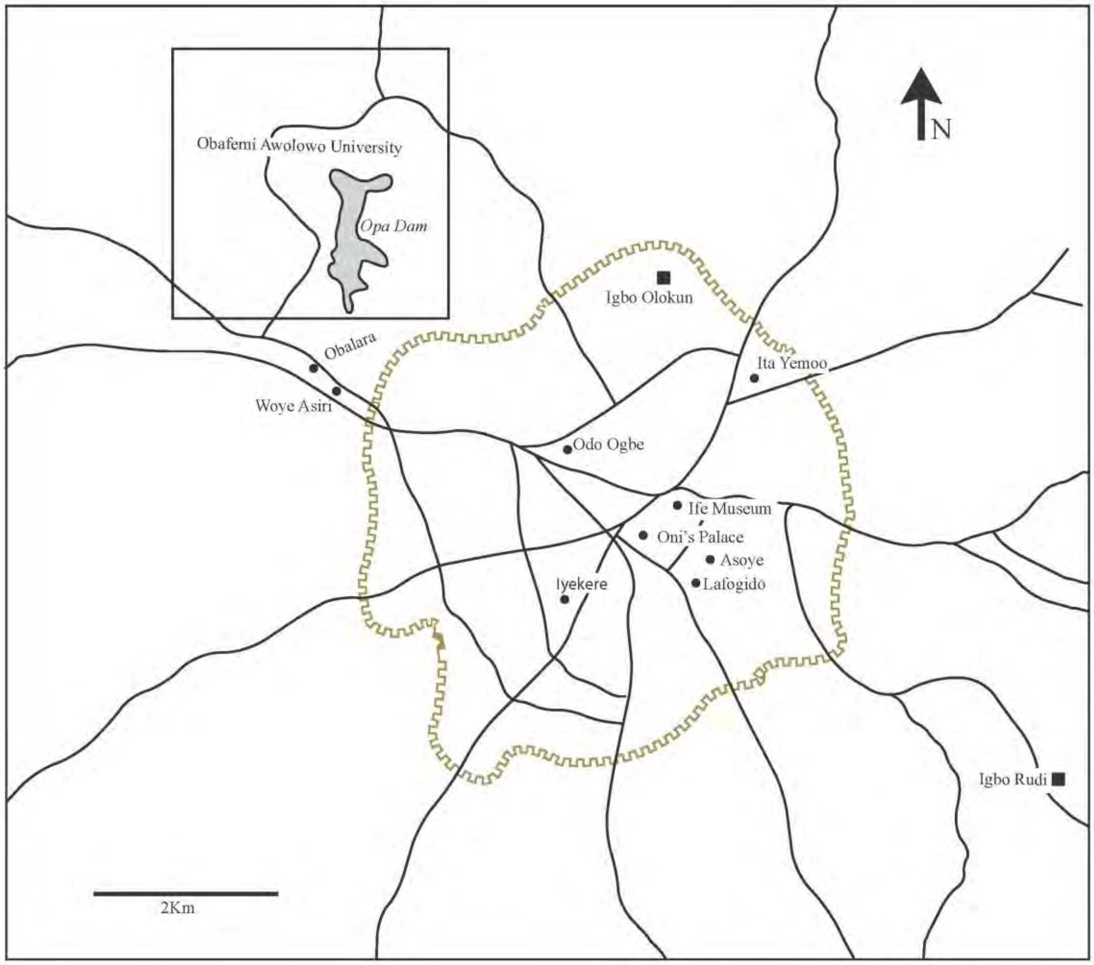

Figure 2.1: Ile-Ife layout, showing the location of Igbo Olokun and Igbo-Rudi.

Considering the possible original size of Igbo Olokun, the site today is significantly reduced. No wonder Eluyemi (1987: 200) refers to the site in its present form as "a gloomy shadow of itself." Human activities, especially modern building construction, have encroached upon the integrity of this site, reducing its size. The urbanization process swallowing Igbo Olokun as well as other sites in Ile-Ife is mostly due to expansion caused by the rebuilding of the city following damage from the war between Ife and its neighbor, Modakeke (Omonisi 1992: Olaniyan 1992). The first Ife-Modakeke war was in the mid-19th century and, since then, there have been several war outbreaks between the two neighbors with the last one in year 2000 (Ogunfolakan 2004; Asiyanbola 2010). The war and the subsequent rebuilding efforts it necessitated have repercussions for this area's archaeology.

Figure 2.2: An aerial view of the site, showing the hypothetical extent of Igbo Olokun. Note the density of building at the site's vicinity.

Another threat to this area's archaeology is illegal digging for ancient glass beads. A local resident told us that they remember seeing many holes in the streets in late 1970s that were later filled with grading equipment when the road was being expanded. These holes may be evidence of protracted looting activities. Frobenius (1968) mentioned that illicit looting occurred at Igbo Olokun. But even his excavations at Igbo Olokun were not that different from looting in terms of how they were conducted. Despite these activities, the surface at the site is still littered with crucibles fragments, glass beads, and occasionally pottery, which are all indication of an archaeological site, but also speak to the site's long history of being disturbed.

As a result of the clandestine digging, urban encroachment, and a fiasco involving the removal of a precious Olokun head from the site, the Federal Government, through the National Commission for Museums and Monument (NCMM), acquired a portion of the land on Lane 6, Irebami area, for conservation. Measuring 21 by 48 meters, the plot is believed to be the location where Frobenius dug up the infamous Olokun terracotta head. The government hopes that by protecting this area it will be able to be used to further education, research, and tourism.

This plot is located on high terrace about 100 meters away from the flood plain of the Esinmirin River. Like the surroundings, the site is littered with crucible fragments and glass beads. Therefore, most of the excavation units reported in this dissertation were placed within the NCMM property and its surroundings. Unlike Igbo Olokun, the other site of excavation, Igbo-Rudi, is located on the outskirts of the city, approximately 6.6 km southeast of Igbo Olokun, and 2.2 km from the Oke-Ogbo junction along the road in front of the Iwara Palace; this road is claimed to be the old route to Ondo town (Ogunfolakan per. comm. 2015). The site is located within a sacred grove. The grove is thought to be one of the early settlements of the Iwara people in Ile-Ife. The Iwara preserved the grove for the ritual coronation of new king. During the coronation, there would be a procession to the grove where rituals are performed for the new king. While the priests and the king go into the grove, families, friends, well-wishers, and observers are not allowed to go beyond a certain point.

The portion of the sacred grove where we carried out our investigation is at the current day boundary of the sacred grove. Although the site is a sacred grove, it has been encroached upon through farming. In fact, the site is presently within a cocoa farm. Mr. Gbadebo Akinola owns the cocoa plantation, which he inherited from his father in 1971 and has been farming on it since then. From our excavation at the site (see Chapter 4), we can say that farming had little impact on the archaeological deposits. Although Mr. Akinola did know that the land has a connection with an older Iwara settlement, he does not fully understand the archaeological potential of the site. Throughout our investigation at the site Mr. Akinola was constantly visiting, and efforts were made to educate him about our work and the archaeology of Ile-Ife at large. We even hired his son who was an undergraduate at the Obafemi Awolowo University, to at times be part of our crew.

The ignorance of Mr. Akinola about the archaeological potential of his farm is understandable because there has never been any serious archaeological interest and investigation of this particular site. Dr. Ogunfolakan was the first to notice some topographic anomalies, which proved to be occupation mounds based on tests we conducted there; the results of these tests are published elsewhere (Babalola, 2011), but further details are presented here.

Contextualizing Ile-Ife in (pre)history

Ile-Ife holds a prominent place in Yoruba history. Ile-Ife's supremacy has been validated by several versions of oral traditions among many Yoruba towns and cities as well as the adjacent Edo speaking region (e.g. Akintoye 2010, Egharevba 1968). The legitimacy of Ile-Ife is also acknowledged in the tradition of origin of groups of people as far as Togo and Ghana.

Despite this significance of Ile-Ife in traditions of origin of many groups and sub-groups in southern Nigeria and elsewhere, there is not much documented about the "holy city" in the record of historical writing. The first account of Ile-Ife in written records dates to the 14th century, compared to the Sahel region of West Africa where historical events have been documented as far back as the 8th century AD by the earlier Arab travelers and merchants.

Ibn Battuta was the first to mention a polity that may have been Ile-Ife in a historical account. He wrote in the 14th century that "Yufi [Ife?] is one of the most considerable countries of the Soudan, and of which the souverain [sovereign] is one of the greatest kings of the country." In the 15th century, Pereira Pacheco – a Portuguese sailor and explorer, described a ruler in the interior of the Bight of Benin "as having the status among the blacks as the Pope is among us." João De Barros (1552) wrote about the custom of the king's coronation in Benin, southern Nigeria:

> "… in accordance with a very ancient custom, the King of Beny [Benin], on ascending the throne, sends ambassadors to him {King of Ogane} with rich gifts to announce that by the decease of his predecessor he has succeeded to the Kingdom of Beny, and to request confirmation. To signify his assent, the Prince Ogane (Ooni?) sends the King a staff and a headpiece of shiny brass, fashioned like a spanish helmet, in place of a crown and scepter… Without these emblems the people do not recognize him as lawful ruler, nor can he call himself truly king.

Although scholars of Yoruba and Benin studies have proposed that the Yufi and Ogane in early Portuguese documents refer to Ife and the Ooni, Ryder (1965) and Thornton (1988) provide arguments for alternatives. Drawing from other early Portuguese documents on the interior kingdoms of the Bight of Benin, Thornton (1998: 355) argues that a state in the Niger-Benue region, perhaps the Igala kingdom rather than Ife, was the powerful religious state referred to in Portuguese document. He further suggests that the Yufi kingdom reference in lbn Battuta's description was a Nupe kingdom. This debate shows the importance of archaeology to understanding the role of Ile-Ife over time.

The historical accounts of Ile-Ife in the 19th centuries and oral traditions depict a city with powerful political and religious influence and sophisticated material culture. Richard Lander, a European explorer wrote about his conversation with a local from whom he purchased some glass objects at Old-Oyo market: "the natives informed us that it was dug from the earth in a country called Iffie … where according to their tradition, their first parents were created, and from whence all Africa has been peopled." (Lander and Lander 1832: 171). Old Oyo was the largest Yoruba kingdom at that time. During the time of the European visit to the interior of the Yoruba region, especially the early 19th century, Ile-Ife was not only lacking the political power accorded her in early historical sources, but had also been sacked at least twice by its neighbor, Modakeke (Akinjogbin 1992). The rivalry between Ile-Ife and Modakeke even continues to the present (Toriola 2001; Asiyanbola 2010). Akintoye's (1970) description of Ile-Ife in the 19th century captures the state of the affairs at that time:

> "… [the] 19th century was a century which saw the subordination of Ife to one of the new states, repeated destruction of the ancient town of Ile-Ife, its repeated and prolonged degeneration into empty jungle while it citizens fled to the villages and farms on enforced exile, the despoiling of its wealth of art treasure" (Akintoye 1970: 34).

The gross lack of political power and influence of Ile-Ife in the 19th century contrasts with the early historical accounts that portray it as wealthy, flourishing, and commanding significant ritual and political importance. Although oral accounts have played a pivotal role in the reconstruction of Ile-Ife's glorious past, earlier archaeological discoveries and investigations in the city have proved to be a much better tool for understanding Ile-Ife's history from the earliest time to the recent past. This chapter will now begin a discussion of the prior archaeological investigations in Ile-Ife. I first discuss earlier discoveries during construction and other activities in the city, and then present other previous archaeological excavations in Ile-Ife.

Prior archaeological investigation in Ile-Ife

Over the course of the last century, several archaeological investigations have been carried out in Ile-Ife. Most of these were prompted by accidental discoveries of archeological materials during the construction of mines and the mining of laterite clay or gravels (Garlake 1974, 1977; Willett 2004). Thus, many of the past excavations in Ile-Ife were salvage operations rather than archaeological investigations. Salvage excavations do not address particular research questions; however, these previous excavations have contributed to our understanding of Ile-Ife's material culture.

The early archaeology of Ile-Ife concerned itself with collecting exceptional artifacts rather than meticulous archaeological record keeping. Willett summarizes this well:

> In any account of Ife, the art receives the greatest emphasis, for until 1949 no serious archaeological work was undertaken. Even since that date the existing literature emphasizes the art rather than the archaeology because it is easier to describe the outstanding individual finds in an interim report than to study the mass of potsherds in detail (Willett 1970a: 244).

Willett (2004: Chapter 1. 2) further suggests that "only relatively rarely have works of art been found by archaeological excavation," meaning that this emphasis on artwork further mischaracterizes the deposits of Ile-Ife. This keen interest in the arts of Ile-Ife explains why art and art history literature make up the bulk of published writing, which discusses the city's history. In order to gain an archaeological perspective, I will discuss Leo Frobenius' account of his archaeological expedition to Ile-Ife in 1910, even though his methods were not rigorous or scientific in nature.

Leo Frobenius and early archaeological discoveries in Ile-Ife

Leo Frobenius, a German anthropologist, was the first to investigate Ile-Ife in 1910. Frobenius' mission was to collect artworks from Ile-Ife. Frobenius first heard about Ile-Ife in 1908 while he was in Timbuktu and Wagaugu. There, he heard people talk about the antiquity of the far southeastern cities, and Ile-Ife was mentioned as the first of the five great cities with impressive antiquity in West Africa (Frobenius 1968: 69). By 1910 Frobenius set out to Ile-Ife to collect antiquities. While there, Frobenius visited several groves including: Ore, Osanyin, Modakeke, Iwinrin, and Olokun. Despite Frobenius' visit to many archaeological sites, his activities in Olokun grove, where he carried out several digs, received the most attention in his book. Although Frobenius (1968: 94) describes his technique as "burrowing," meaning unsystematic digging, he provides us with some useful information on the stratigraphy of his excavation. Willett (2004 Chapter 1.2) has this to say about Frobenius' work: "Frobenius conveys a clearer picture of Olokun grove in spite of his haphazard method." Frobenius did not provide detailed information about the area and the exact location he excavated; however, his reference to "shafts" in his book suggests that the units might have been round as opposed to the conventional square or rectangular archaeological units.

Frobenius does provide some sense of the stratigraphy, depth, and material contents of his excavations. He describes the upper 35cm as very hard compact soil overlying a red homogeneous fire-clay with decomposed quartz. He encountered pottery at two meters depth, charcoal and ash at five meters depth, and crucible and crucible fragments in the bottom of a shaft at approximately between 3.5 and 7 meters deep (1968: 94, 309). The most famous discovery of Frobenius is a brass head suggested to be a figure of Olokun. The figure is about 34.5cm in size. Amazed by this figure, Frobenius comments:

> Before us stood a head of marvelous beauty, wonderfully cast in antique bronze, true to the life, incrusted with a patina of glorious dark green. This was, in my deed, the Olokun, Atlantic African's Poseidon! (Frobenius 1968: 98)

The figure was later discovered to be made of brass and not bronze, as well as later interpreted to represent an Ooni instead of Olokun (Drewal and Schildkrout 2009: 27). Frobenius also discovered quartz sculptures, several terracotta, crucibles (which he first described as "glazed potsherds,") and glass beads at Igbo Olokun and other shrines and groves in Ile-Ife. Based on these finds, Frobenius concludes that the early Ile-Ife occupation was "reminiscent of Ancient Greece" (1968: 88-9), which meant that he thought that Yoruba culture was a crystallization of western civilization. Frobenius' interpretation of the origin of Yoruba civilization needs no further criticism here, as it has often been refuted.

Despite the problems associated with Frobenius' methodology, analysis, and interpretation, his work is still important for a number of reasons. First, it was the only "archaeological report" on Ile-Ife until the time of William Fagg and Kenneth Murray in the 1940s and 50s. Second, it brought Ile-Ife into the world of archaeology, history, and art history. Finally, it triggered further interest in the antiquity of Ile-Ife by the colonial government, and also aroused the interest of many local people in Ile-Ife to their cultural heritage.

Other early discoveries

Another important discovery at Ile-Ife involved the uncovering of eleven bronze figures at Wunmonije compound during the digging of a house foundation in 1938. A few years later, an additional six heads were found from the same compound; these figures consist of mostly bronze heads. With this discovery, "the art world began to pay serious attention to the art of Ife" (Willett 2004: Chapter 1. 2). By 1948 the then-current Ooni had sent the figures to the British Museum to demonstrate the richness of his heritage (Drewal and Schildkrout 2009: 4).

Again in 1957, workmen found more sculptures at the site of Ita Yemoo in Ile-Ife (Willett 1959; 2004). These included seven bronze figures; the "Ooni figure," a royal couple in interlocking arms and legs, a vessel, two staffs, and another two staffs. Three out of the four staffs have figures of gagged human heads on them (Willett 2004: Chapter 1. 2). A potsherd pavement was also uncovered at the site, but it was destroyed in the process of excavation. The figures are suggested to have been found lying on the pavement, which may indicate an ancient shrine (Willett 2004: Chapter 1. 2).

The Ita Yemoo discovery brought a significant change to the archaeology of Ile-Ife. It was after this discovery that a need for systematic large-scale excavation was conceived. As a result, Frank Willett was invited to carry out archaeological excavations at the site. The excavations by Willet and others after him saw a need to apply a more scientific method of inquiry to the reconstruction of cultural traditions in early Ile-Ife. I will discuss Willett's excavations and others below. Before that, however, I discuss briefly the excavations carried out by William Fagg (a government archaeologist) and Kenneth Murray (the Surveyor of Antiquities) and their team between 1940s and 1950s. I have grouped these projects together as Ile-Ife's "early excavations."

Early excavations in Ile-Ife

After the discovery at Wunmonije Compound there was a rush to collect more material for preservation, and to document areas of archaeological significance, including shrines and groves. The later task was fulfilled in 1943 when Kenneth Murray compiled a list of shrines, groves, and other archaeological sites around Ile-Ife. This list was updated in 1948 and subsequently made available to the Ile-Ife Museum (Murray 1948).

Between 1949 and 1953, Kenneth Murray, Bernard Fagg, William Fagg, and A.J.H. Goodwin developed a program for excavation in and around Ile-Ife to reveal and collect more materials belonging to early Ile-Ife; this project aimed to shed light on the origin and chronology of Ile-Ife. Their excavations were the first efforts toward coordinated archaeological investigations in Ile-Ife. The team's primary mission was to excavate more shrines and groves in Ile-Ife in order to find more artwork like that that had been collected previously. From the excavations, they recovered numerous artifacts including terracotta and pottery, although most of it was fragmented. They also encountered features such as potsherd pavements and several pits. Fagg (1953: 126) describes the pits as "a large number of underground chambers with restricted access shafts, which were suggested to be a funerary chamber" (Fagg 1953:26). Because of the fragmentary nature of the terracottas and other artifacts from the excavations, Fagg (1953: 125) abandoned the excavations, concluding that these excavations would not yield the results he desired, namely the discovery of more exquisite bronze heads and other fully-articulated artworks.

Other Prior Excavations in Ile-Ife

As discussed above, the discovery at Ita Yemoo in 1957 served as a prelude to a new era in the archaeology of Ile-Ife. At this time there was a keen interest in understanding what these discoveries could say about the early occupation of Ile-Ife. Although archaeological sites were still being discovered accidentally, most excavations at this time were salvage operations. By and large this period of archaeology still followed an art historical approach. Research focused on constructing stratigraphic sequences and chronological frameworks with the aid of radiocarbon dating. Also, great attention was given to the chemical analysis of the composition of materials, including bronze, brass, and glass (e.g. Davison 1972; Werner and Willett 1975; Willett 1977). Willet's excavation at Ita Yemoo jump started this important period in the archaeology of Ile-Ife. Thus, in this section, I will first discuss Willet's excavation at Ita Yemoo and other places in Ile-Ife. Then I will discuss other excavations in Ile-Ife from the 1960s to the present.

Arriving in Ile-Ife at the invitation of the Nigerian Antiquities Department in 1957, Willet conducted pilot excavations at Ita Yemoo between 1957 and 1959. Following this work, Willett continued to excavate at Ita Yemoo between 1962 and 1963 (see Appendix 2.1 for the details of the excavations). Among other excavation units, Willet excavated a trench across the earthwork at Ita Yemoo. The excavation was aimed to establish a relationship between the occupational deposits at Ita Yemoo and dated artifacts found in Ile-Ife (Willet 2004: Chapter 1.2). During the excavations, Willet collected many charcoal samples, which were radiocarbon dated to the 10th – 14th centuries AD (Willet 2004). In 1959, Willet also excavated the Catholic mission site at Lagere in Ile-Ife where an extensive potsherd pavement was uncovered. Willet also encountered a grave and associated human remains at this site.

Between 1960 and 1961, Willet excavated at Orun Oba Ado[5] in Ile-Ife. In the two trenches excavated at Orun Oba Ado, Willet encountered eleven pits, which are thought to have been intended for burial of the heads of deceased Benin kings. Although no skeletal remains were found, Willet suggests that they could have fully decomposed due to poor preservation in the region, or that perhaps, according to custom, "only nail-paring and hair-clippings from the corpse were taken to Ife for burial" (Willet 2004). Other finds associated with the pits are pottery, terracotta, and glass beads. Charcoal samples were also collected from the pits; these samples place the occupation of Orun Oba Ado to a period spanning the 6th to the 10th centuries AD (Willet 2004). The radiometric dates

[5] Orun Oba Ado is reputed to be the burial site of the heads of the deceased kings of Benin. Bradbury, R. E. (1959) documented such practice in 1888, which is suggested to be the last occasion of the tradition.

from Orun Oba Ado are significant because they pushed the occupation of Ile-Ife back in time.

Following Willet's recommendation, Oliver Myers excavated at Igbo Obameri near Moroko road, Ile-Ife in 1966. According to Myers the "principal feature at the site is a mound in the sanctum under which Obameri – brother of Oduduwa – is said to have been buried" (Myers 1967: 7). Although the shrine was still in partial use as at the time of the excavation, the excavation exposed five more rooms believed to have been part of the shrine. The deposit at Igbo Obameri was very shallow with "fragmented classical Ile-Ife terracotta as the major finds" (Myers 1967: 6). The radiocarbon date from Igbo-Obameri is controversial. The same charcoal sample was analyzed two times in the same laboratory and gave different dates separated by three decades (Myers 1967: 7). This means that the occupation of Igbo Obameri cannot be placed within the 'classical Ife' period. No further excavation was carried out at the site to redress this issue.

In the same year, Myers (1967) also excavated at the Oduduwa College site. The site was discovered accidentally by a worker whose digger hit a terracotta head while enlarging a fishpond. Myers refers to the excavation as an "emergency rescue operation" (1967: 8). During the excavation some terracotta and pottery were found with some pits. Two of the pits discovered at the Oduduwa College site were burials with some human bones (Myers 1967: 10). Several potsherd pavements of different designs were also exposed. From these materials, Myers (1967: 11) observed that the site might be important, however he did not publish a comprehensive report of the excavation nor any of the finds and no follow-up work was carried out at the site.

Ekpo Eyo was the first indigenous professional archaeologist to excavate in Ile-Ife. In 1967, he carried out excavations at the Odo Ogbe site in Ife. The excavation uncovered pit features with pots embedded in them. Eyo interpreted these features and associated ceramics as evidence of a tradition of "pit and pot" burials in early Ife (Eyo 1974: 106). Radiocarbon dating indicates that this site was occupied from the 11^{th} - 17^{th} centuries AD. Eyo also excavated at Lafogido, near the king's palace in Ile-Ife; here Eyo found pots with animal figures. Based on the arrangement of the pots and terracottas, Eyo concluded that the deposits were in primary context, and represent the material culture of a temple (Eyo 1974: 107). Another radiocarbon date from Lafogido dated this deposit to the 12th century AD

The excavations by Peter Garlake at Obalara compound and the Woye Asiri family land in 1971 and 1972 are the best-documented excavations of Ile-Ife (Garlake 1974, 1977). Like many other excavations at Ife, Garlake's excavations were instigated as a salvage operation. Garlake's research includes the establishment of an archaeological context for some terracotta that earlier came from the sites, in order to create a comprehensive stratified assemblage of pottery for developing a ceramic typology for early Ife (Garlake, 1977: 57).

Garlake's (1974) excavations at Obalara were located outside the western wall of Ile-Ife, and revealed several potsherd pavements and numerous terracottas. The pavements divided the site into two halves to the west and to the east. Five of the pavements have similar characteristics – they are constructed with potsherds lying on the edge in herringbone pattern. Base on the similarities, Garlake (1974: 120) suggested that buildings in early Ife shared common planning. This planning pattern reveals the spatial behavior of the past occupants of Ile-Ife. The complexity of the building is reflected in the pavement design suggesting that both domestic and ritualized spaces co-existed within a building or building complex. The Obalara site is dated to between the 12th and 14th centuries AD. In 1972, Garlake also excavated at Woye Asiri family land in Ife.

The excavations at Woye Asiri focused on confirming the interpretations made about the Obalara site (Garlake 1977: 58). Like Obalara, potsherd pavements were the major features encountered at Woye Asiri, which Garlake suggests might represent domestic family dwellings (Garlake 1977: 66). Unlike many excavations in Ife, no terracottas were recovered from the Woye Asiri excavations (Garlake 1977: 72-91). Based on the result of the radiocarbon dates from Woye Asiri, the large amount of material culture recovered, and the stratigraphic information, Garlake was able to delineated three occupational horizons for the site. Horizon I and II are dated to the 12th century AD, representing the first occupation while Horizon III represents the area's abandonment in the late 14th century AD.

In 1975, Adeduntan (1985) excavated a site at Ayelabowo where he recovered several glass beads and other glass-related materials. According to Adeduntan, half of the intact beads recovered from Ayelabowo were not perforated. This lack of perforation and the presence of other glass waste led Adeduntan to conclude that the Ayelabowo site was a glass beadmaking site dating to the classical Ile-Ife (Adeduntan 1985: 165). This excavation provided vital data on the possibility of another glass-working site at Ile-Ife; unfortunately no further excavations were conducted at the site, and that excavation was not fully documented.

In the mid-1970s through 1980s, Eluyemi championed a plan to investigate Ile-Ife archaeologically by thoroughly documenting all archaeological and historical sites, both old and new, prompted by sprawling urban development. In this capacity he personally monitored several construction and quarrying activities in Ife city. The finds were reported as short journal articles (e.g., Eluyemi 1975, 1977). For example, Eluyemi carried out a follow-up rescue excavation at Aroye compound where he recovered three whole pots (Eluyemi 1985). No charcoal samples were recovered from Aroye site for radiocarbon dating. However, based on the similarities between decorations on the pots and classical Ife materials, Eluyemi suggested that the Aroye site belongs to the classical period (1985: 107).

In the 1980s, Eluyemi carried out excavations at the Igbo Olokun site. His excavation recovered numerous glass beads, crucible fragments, and furnace structures (Eluyemi 1987). The glass beads are described by shape, color, and diaphaneity. Eluyemi (1987: 214) concludes that the context from which glass beads were retrieved is dated to the last quarter of the 9th century AD, which places glass bead production to the classical era. Eluyemi's excavations are the most recent excavations of Igbo Olokun, yet he fails to give detailed stratigraphic information.

In 1981, the staff of the National Commission for Museums and Monuments, under the direction of Mrs. Fatunsin, conducted an excavation of an occupational mound at Igbo Oramfe. The excavation was to investigation the antiquity of the site, particularly to validate whether or not the occupation of the site is connected to oral traditional account that claimed Oduduwa first settled on or around the hill. The excavation did not yield material of great time period. The recovered material consisted mostly of modern material. Also no radiocarbon dates were generated for Oramfe site, perhaps, because no good reliable samples were recovered from the excavations. However, there were abundant cowry shells of *Cypraea annulus sp.* Cowry shells were not common in West Africa until the 16th century; in fact, large-scale importation of cowry shells into Yorubaland through the Atlantic commerce did not happen until late 16th through early 17th centuries. In the absence of radiocarbon dating, the presence of cowry shells may suggest a date of between 17th or 18th centuries for the Igbo Oramfe occupation. Nevertheless, it should be noted that this was the only archaeological excavation at the site; further investigations in different parts of the site may yield other results.

Since Frobenius' time, Ile-Ife has witnessed numerous archaeological excavations vis-à-vis accidental discoveries. In fact, archaeological materials are still being discovered by chance in Ile-Ife, and archaeologists working in the city are still in the business of rescuing sites and making the effort to report their findings (e.g. Ogunfolakan 2001, 2002). However, since the report of Garlake's excavations at Obalara and Woye Asiri, no major excavation report has been published on Ife; the report in this dissertation will be the first effort to describe major systematic excavations at Ile-Ife in the last three decades.

The richness of material culture from Ile-Ife has earned it the appellation 'culture bank of the Yoruba.' In the section that follows, I discuss the variety of material culture that has dominated the archaeological and art historical discourse of Ile-Ife, and West Africa as a whole. I will describe common finds and discuss their significance for understanding regional and trans-regional processes in antiquity. However, before I discuss the material culture of Ile-Ife, I will briefly consider previous excavations at Igbo Olokun. Although excavations at Igbo Olokun had been sparsely mentioned earlier, I desire to present them in a more detailed manner.

A Summary of Previous excavations at Igbo Olokun

The archaeological potential of Igbo Olokun was revealed with Frobenius' (1968) work at the site. . His choice to dig at Igbo Olokun was informed by the information he gathered from local people about the artifacts that had been dug up at the site previously. From the many pits he dug, he recovered terracotta, crucibles covered in fused glass, glass beads, pottery, and a bronze head, which was said to be the figure of Olokun (Frobenius 1968). Fagg and his team also excavated at Igbo Olokun in 1950s. The excavations yielded crucibles, pottery, and terracottas. What we do know about Fagg's excavations is that the material collected was fragmentary and that their arrangement does not suggest materials in their primary context (Fagg 1953).

In late 1970s, Eluyemi initiated archaeological investigations at Igbo Olokun, and carried out reconnaissance and excavation at the site. Eluyemi identified and excavated fourteen furnaces, which were suggested to have been used in glass bead production. Along with 180 glass beads collected on the surface, he also excavated 188 glass beads. Other materials such as crucible fragments, pottery and pottery plugs, tuyere fragments, and slag pieces were also recovered (Eluyemi 1978: 200).

As important as these previous excavations at Igbo Olokun are for their evidence of glass bead manufacture (Fagg 1953; Frobenius 1913; Willett 1977) and to a lesser extent, iron working (Eluyemi 1987), they do not include a detailed description of the method used, nor the stratigraphy of the site. Information on the spatial organization of artifacts in the excavation units, in terms of their sizes and location within the site, is also limited or lacking. All these details are essential to understand the process and technique of production of glass beads in ancient Ile-Ife. In Chapter 5, I describe my excavations and present the stratigraphy and chronology of the site. The next section in this chapter discusses the material culture of Ile-Ife which has already been recovered. It examines their typological and cultural significance as they relate to the historical reconstruction of life in ancient Ile-Ife.

Ile-Ife Material Culture

Bronze, Terracotta, and stone figurines

Artworks in the form of bronze figures, terracotta, and stone figures are common archaeological finds in Ile-Ife. These materials have attracted interest for over a century. Terracotta, bronze or copper alloy objects and stone figures made Ile-Ife known to the world of academia and art collectors (Willett, 1967: 18-51, 57-81). The objects are very fine such that they have over-shadowed the rest of Ife's archaeology, and have been overrepresented in the formulation of its history (Willett, 1970: 244; Schildkrout 2010:2). Naturalism is the hallmark of Ile-Ife's classical period sculpture. Drewal (1989) has classified Ile-Ife artworks into minimalist (stone monoliths combined with iron), stylized (stone and terracotta), and naturalism. However, Fagg and Willett (1960) argue that only the faces of the classic Ile-Ife figurines are naturalistic and that the rest of the body is more stylized. In spite of Fagg and Willett's claim, naturalism remains a significant criterion in identifying Ile-Ife artworks.

Ile-Ife artworks are made in brass, terracotta, and stone using different techniques. The brass objects are mostly alloy of copper and zinc (Willett 1977). The technique of bronze casting has been identified as the "lost wax" process. This technique is significant in the Ile-Ife sculpting industry and has been discussed in detail by several West African scholars (e.g. Willett 1977, 2004). Some of the brass artworks found at Ile-Ife are representations of humans including naturalistic human heads, gagged human heads, and masks. Brass objects such as pendants, rings, and staffs were also recovered from sites around Ile-Ife in 12th – 15th century contexts. Compositional analyses of the brass recovered in archaeological contexts from Ile-Ife have shown that the metals were imported from outside Ile-Ife (1977: 23). This shows the early contact of Ile-Ife with the outside world, but not necessarily the Atlantic world. The raw material for brass working could have reached Ile-Ife through other significant trade centers in early West Africa.

Despite the diverse brass objects found in Ile-Ife, it appears that most of the artworks were associated within the domain of the royal elites. The brass figures represent the royal elites in their apparel, or symbolize the paraphernalia of their office and authority. For example, one of the bronze figures from the excavation at Ita Yemoo is suggested to represent the Oni in his royal regalia with a horn and staff in his hand, both signifying power and authority. Another pair of bronze objects represents the Oni and his wife (Willett 1959: 190-1). Also the staffs that include representations of gagged human heads are suggested to be staffs of political office (Willett 1959a & b).

However, the conventional interpretation of Ile-Ife brass heads and other figures as representation of political elites has been recently challenged (Abiodun 2014). Rather than interpreting the Ife heads as representations of different kingly figures, Abiodun (2014) argues that the figures are material expression of *oriki* (praise songs). Since the faces of the Yoruba kings are usually concealed to the public, his conclusion is that the copper alloy heads of Ile-Ife are representations of *Ifa's* (the Yoruba divine divination) priests. Abiodun's reinterpretation of the Ife copper alloy figures is an interesting development in the scholarship of Yoruba and African studies, however, as suggested by Ogundiran (n.d.) Abiodun's "re-reading of the Ife copper-alloy figures raises more questions than he has answered."

Terracotta sculptures are molded out of locally-sourced clay. Like the bronze works, terracotta is also very common in Ile-Ife. Ife terracottas are made in different styles and depict both human and non-human figures. For example, many fragments of terracotta human parts have been recovered from Iwinrin grove (Drewal and Schildrout 2009). Also, Eyo's excavations at Lafogido uncovered several pots with terracottas depicting animals that appear to be pot lids (Eyo 1974: 106). Four of the animal heads were identified as depicting an elephant, ram, chameleon, and antelope. Another animal head was said to represent a "mystical animal" composed of several animals such as a hippopotamus, bush pig, and leopard. Terracotta shaped like human arms and heads were also found at the Lafogido site (Eyo 1974: 107). This difference in the style of Ile-Ife terracottas versus those recovered from nearby sites may demonstrate the preferences of each cult to its own artist (Fagg and Willet 1960: 30). In addition, Fagg and Willett (1960) have argued that the internal portions of terracottas, compared to the internal portions of Yoruban pottery, are generally poorly fired (Fagg and Willett 1960: 31). This observation does not undermine the intricacy of the Ile-Ife terracotta. In fact, terracotta has been a hallmark of Ile-Ife archaeology, recovered from almost all the major excavations in the city. They are have contributed significantly to our understanding of past lifeways and events in early Ile-Ife.

Unlike the bronze artworks, terracotta sculptures represent a much wider cross-section of life in early Ile-Ife. In addition to depicting royalty adorned with beaded necklace, anklets, and bracelets, some terracotta depicts people with disability and disease, commoners, and even none Ile-Ife people; this diversity highlights the cosmopolitan nature of the city. The variability of terracotta finds show "affects" in early Ile-Ife, which Suzanne Blier (2010, 2015) defines as the state of emotional expression including anger. In a similar vein, Garlake (2002: 134) suggests that Ile-Ife artworks, in particular terracotta, have emphasized the "polarity between serenity and violence, calm and terror, health and sick." Indeed, no other categories of materials from Ile-Ife capture human activities and emotions in early Ile-Ife, as does the terracotta artifacts.

Despite the significance of terracotta in the archaeology of Ile-Ife, stone figures have also been frequently recovered at Ile-Ife. The stone sculptures are mainly made from three types of materials: granite, quartz, and soapstone. Geological investigations in and around Ile-Ife reveal the presence of these materials locally (see the earlier section on the geology of Ile-Ife, Jeje 1992). Granite was used in the carving of the monoliths from Ore grove and the Opa Oranmiyan (Oranmiyan's staff). Occasionally stone objects from Ife are decorated with iron. For example, the mudfish and the Idena (gate keepers) from Ore grove, and the Opa Oranmiyan all have some iron decoration. Although quartz sculptures are rare in Ile-Ife assemblages of stone works, they are important because they have shaped the international perception of Ile-Ife. In particular, the intricacies of the three remarkable quartz stools that the then reigning Ooni of Ife (Oba Adelekan Olubuse) gave as gifts to Sir Gilbert Carter (a colonial official) in 1896 have become internationally acclaimed. One of the stools was donated to the British Museum, another resides in the Lagos Museum, and the third stool has gone missing. Like some of the brass figures, these stools have also been interpreted as elite objects. Schildkrout (2009: 20, 87) suggests that the looped handle of the stools may represent an elephant's trunk; since the elephant is associated with royalty; the stools are likely royal seats.

Soapstone objects have also been found in Ile-Ife in more chronologically diverse contexts than other material types. The chronology of the stone figures is difficult and uncertain. Although most of the artifacts associated with contexts that have yielded carved stone objects are dated to the 12^{th} - 15^{th} centuries, scholars have tended to generalize that the stone materials belong to the same periods. While other scholars have raised the possibility that stone craftsmanship began much earlier in Ife (e.g. Willett 2004; Ogundiran 2005; Schildkrout 2009), with the exception of soapstone carve tradition, which Fagg and Willett (1960: 30) suggests continued in use during the post-classical era (after 15^{th} century) and possibly until the recent past. The early possible date, although mostly speculative, was based on the relatively crude nature of most of the soapstone sculptures compared to the brass and terracotta figures. If the finishing was a criterion for identifying earlier stone sculpture, then the three quartz stools are an exception to the rule. The poor archaeological context of the stone artifacts inhibits a complete understanding of the material. Compared to the stone artifacts, there are better and more reliable archaeological data for pottery from Ile-Ife.

Pottery

Pottery is one of the most common archaeological materials that have been recovered from Ile-Ife. Almost all the excavations carried out in Ile-Ife encountered pottery (e.g. Garlake 1974, 1977; Eyo 1970, 1974a & b; Willett 2004), including many complete pots (e.g. Eluyemi 1977). However, prior to Garlake's (1974, 1977), detailed publications on Ile-Ife pottery from Obalara and Woye Asiri, there were few comprehensive pottery analyses. Although Willet (1967) was the first to propose a scheme of classification for Ife pottery, his classification system was not widely adopted. This may have been for the best because many of Willett's samples were taken from potsherd pavements, a method that offers sherds too fragmentary to provide comprehensive information.

Garlake's (1974, 1977) pioneering studies of Ile-Ife pottery provided significant details that have helped make sense of Ile-Ife pottery. A detailed discussion of Garlake's procedures and results are presented in Chapter 5. Garlake (1974, 1977) has shown that there were changes in the decoration of Ile-Ife pottery from 12th to 15th century AD. During this period, ritual pots were mostly decorated with reliefs of anthropomorphic and zoomorphic motifs, as well as carved roulettes (as opposed to string roulettes; Willett 1967; Garlake 1977).

Potsherd Pavements

Potsherd pavements are a common feature in Yoruban sites. They are a distinctive form of floor tile made with potsherds laid out in either a herringbone or brick pattern. Potsherd pavements have different patterns. Excavations by Garlake at Obalara and Woye Asiri uncovered several pavements (1974, 1977). Most of the pavement uncovered at Obalara had strips of stone (broken, unweathered quartz chunks and occasional large iron stone nodules) with potsherds laid on edge in a herringbone pattern. While some pavements were flat, others contain altars. These alters are usually raised higher than the pavement surface and they are suggested to be places for ritual activities such as the placement of offerings and pouring of libations (Garlake 1974).

Archaeological evidence has revealed that courtyards or verandas in residential architecture or temples/shrines were paved in Ile-Ife (Shaw 1978: 144; Garlake 1978: 132). The pavements uncovered at Ita Yemoo underneath the town wall were dated to the 12th century AD (Willett 1967, 1969, 1971). Recent excavations at Ita Yemoo by Gerard Chouin and Adisa Ogunfolakan uncovered potsherd pavement at approximately 1.3 meters below the surface of what seems to be the remnant of Ife's inner wall (2015: 13); no radiocarbon dates are yet available from this research. This project will help to better understand the chronology of the wall in relation to urban development and expansion in early Ife (Chouin and Ogunfolakan 2015:10). Other radiocarbon dates between the 13th and 15th centuries, associated with pavements, were obtained from the Obalara and Woye Asiri sites (Garlake, 1974).

At Obalara, Garlake (1974) uncovered several pavements most of which were made with a combination of sherds and stones (1974). Artifacts including complete vessels, grindstones, mullers, a goat mandible, and red clay were found associated with some of the pavements. A complete pot with a flared neck and sculptured relief on the body was also found embedded at the center of one of the pavement. Garlake (1977: 63) suggests that the pot would have been used for "ritual to receive libations offered to the gods to whom the altars were dedicated" before being recycled for use as a pavement. The presence of the pavements reveals not only complex architectural techniques, but also, as argued by Garlake (1974: 120), demonstrates that "the building or complex of buildings to which the pavement belonged shared a common basis for their planning." This building technique at Obalara was the norm in early Ile-Ife, as evident at other sites. For example Garlake's (1977) excavation at Woye Asiri revealed ten pavement complexes. Based on their location within the site, Garlake grouped these pavements into two groups: western (I-VII) and eastern (VIII-X). These pavements were similar to those at Obalara. The occupation of Woye Asiri is dated to between early 12th and 15th centuries (Garlake 1977: 72).

Potsherd pavements of the same type in Ile-Ife have been reported from other places in Yorubaland: Ila Orangan, Iresi, Asi, Oyan (Ogunfolakan 2001); Ilare

(Ogundiran 2000); Ilesha and Itagumodi in Osun State (Agbaje-Williams 1995, 2001, 2006 Personal Communication); Ibadan in Oyo State (Adekola 2007 Personal Communication); and Oro in Kwara State (Usman 2012). However, most of these potsherd pavements outside Ile-Ife are largely undated. The lack of reliable dates from other potsherd pavement sites in Yorubalad makes the historical narrative on the spread and origin of the tradition impossible to discern. Scholars working at locations outside Ile-Ife need to start making chronometric dating of these sites a priority in order to understand the history of these features.

Earthworks

Remnants of concentric earthworks have been identified in Ile-Ife. These earthworks are characterized by two major concentric walls (a larger one the outside and smaller one on the inside) with several loops added to them. Although Frobenius (1968), Fagg (1953), and Willet (1967) acknowledged the presence of the walls, Peter Ozanne (1969) was the first to carry out an archaeological survey of the walls. Ozanne's report (1969) on the Ile-Ife walls remains the only available detailed literature on the subject. There is, however, an ongoing effort to reinvestigate the walls in order to gain information on the city's development (Chouin and Ogunfolakan 2015).

Ozanne's investigation of the walls lasted for six months with the aim to answer questions relating to the origin, development, and fall of early Ile-Ife (1969: 28). His survey revealed that two walls were built on top of each other: Ozanne (1969) refers to these walls as the medieval (older) and the modern (newer).

The medieval Ile-Ife walls were up to 4.2 meters high and 2 meters thick without any form of ditch on the outside. He identified ten entrances along the medieval outer wall, which, he argues, lead to ancient roads that connect Ile-Ife with other towns such as Benin, Old-Oyo, Ilesha, and Ede (1969: 34-5). In order to accommodate more people and heighten the security of the town, loops (additional strips of earthworks smaller in length and intended to include a new territory into the old) were added to the medieval outer wall. The modern walls are more pronounced in the town and are likely the ruins of the walls left today at Ile-Ife. They have adjoining ditches, V-shaped tapering down to about one foot at the bottom at a depth of about 2.5 meters to the surface (Ozanne 1969: 37).

At their deepest point the height of the wall from the bottom of the ditch was between 3.7 and 4.5 meters. Ozanne (1969:38) states that the height would have been far more than this in the past, suggesting an original height of between 5 and 8 meters (1969: 38). The entrances are standardized with perhaps tower at the outer corner (Ozanne 1969: 39). The tower resembles the type in the Old-Oyo empire, which suggests that the modern wall may have been built around the 19th century, an era of turmoil and demographic change in Yorubaland due in part to the southern invasion of the Nupe people and the eventual fall of Old-Oyo to the Fulani attack. During this period, communities were strengthening their defense systems. The displaced populations were adopted by neighboring communities leading to drastic population increases. Thus, Ozanne (1969) concludes that the Ile-Ife walls reflect the expansion of Ile-Ife as a result of population growth.

Crucible, glass debris, and glass beads

Crucibles, glass debris, and glass beads are ubiquitous materials in the deposits of Ile-Ife. Almost all known archaeological excavations in Ile-Ife have recovered glass-related materials. Frobenius (1968) was the first to encounter a crucible in Ile-Ife, which he first described as glazed stone then later identified as a glass-making crucible. Crucibles are recognizable due to glass encrustations with glass colors that include blue, green, blue-green, red, and black. They are flat-bottomed ceramic vessels with globular bodies, with diameters ranging from 18–30 cm (Frobenius 1968; Willet 2004). Crucibles have been documented by early archaeological investigations in Ile-Ife (in contexts dated to between the 12th and 15th centuries; Willett 1967), and through chance discovery for several decades. Crucibles have occurred mostly in fragments. However, complete or mostly-complete crucibles have been recovered from Igbo Olokun, Itajero, Ita Yemoo, Obalara, and Woye Asiri (Frobenius 1913; Fagg 1953; Willett 1967; Eluyemi 1987; Garlake 1974,1977). Recently Professor Ige (2010 personal communication) of the Natural History Museum OAU mentioned the occurrence of crucibles at the Mayfair area along Ibadan Road, in an undated deposit. Similarly, Ogunfakan of the same department at OAU reported finding a large crucible fragment along Ooni Ilare Street. A complete crucible vessel believed to have been recovered during construction or mining in Ile-Ife is on display at the British Museum. Also there is another complete crucible vessel from

Ile-Ife on the display gallery of the National Museum in Ile-Ife. Despite the long tradition of collecting, recovering, and curating crucibles at Ile-Ife, we still lack detailed studies of these high-temperature vessels.

Glass beads have been found in archaeological deposits in Ile-Ife for over a century. Willett (1967) reported glass beads from Ita Yemoo, Orun Oba Ado, and Olokun grove during his archaeological excavations in the 1950s and 60s. Garlake (1974, 1977) also recovered and reported glass beads from the excavations at Woye Asiri and Obalara. From 1970s through 1980s, Eluyemi recovered glass beads, including over 400 from Olokun grove (1987). Although most of the reports of glass beads lack contextual details, they have provided us with a preliminary view of the chronology, physical attributes (color, shape, and diaphaneity), and chemical signatures of Ife glass beads (Willett 1967, 1977, Davison *et al*. 1971, Eluyemi 1987). The preponderance of glass beads in the archeology of Ile-Ife has attracted local interest. This interest has led to decades-long traditions of clandestine digging at the ancient sites for glass beads (Eluyemi 1987).

Prior to the analysis of a few Ile-Ife glass beads by Davison *et al.* (1971) and the publication of Willett (1977), we knew very little about the characteristics of Ile-Ife glass beads beyond what the Lander brothers described in the early 19th century: "it consists of a variety of little transparent stones, white, green, and every shade of blue …" (R and J. Lander 1832: 180). Ile-Ife glass beads are now generally accepted to be of various colors (blue, green, brown, yellow, red, clear, multicolor), shapes (circular, tubular, round), and diaphaneity (opaque, translucent, diachroic; Davison *et al.* 1971; Willett 1977; Garlake 1974, 1977; Eluyemi 1987). Although there is no classification model for Ile-Ife glass beads, previous research has revealed some basic characteristic of Ile-Ife beads, which has helped to further more complex investigations of the materials.

In addition to the physical description of Ile-Ife glass beads, scholars have also carried out chemical analyses on the glass beads to understand the source of raw materials used in their manufacture. The works of Davison (1971) and Willet (1977) on the origins of the raw materials for Ile-Ife glass beads suggested that Ile-Ife imported glass for the manufacture of beads from European and Islamic countries (Davison 1972; Willett 1977:16). Robertshaw *et al* (2003) have also argued that glass ingots or unfinished products were imported and used to manufacture glass beads at Ile-Ife.

However, a recent chemical analysis of Ile-Ife glass beads has revealed that the raw materials were most likely locally-sourced (Lankton *et al.* 2006). This new perspective on early glass production in Ile-Ife needs to be given more attention. Efforts should be made to create classificatory schemes for Ile-Ife glass materials from archaeological sites with stratigraphic integrity. Chapters 7 and 8 of this dissertation raise and address issues relating to enhancing our knowledge of Ile-Ife glass and the glass bead industry.

Classification and chemical compositional analyses of these materials are instrumental to our understanding of in the early urban center. The chronologies and periodization of Ile-Ife are directly related to the material culture and this historical narrative is discussed in the next section. I first discuss an overview of the chronologies of Ile-Ife. Next, I examine the three periods of Ile-Ife prehistory: the early/Period I prior to AD 900, Period II from AD 900-1500, and Period III from AD1500 onwards.

Cultural Traditions, Chronologies, and Periodization of Ile-Ife Prehistory

This section discusses the view of different scholars on chronology and periodization. I will first present an overview of the chronologies of Ile-Ife by different scholars. I will then discuss the historical episodes at Ile-Ife under three periods: early/Period I (pre-10th century), Period II (10th–16th century), and Period III (Ile-Ife after the 16th century). I establish the 10th century as the beginning of the Classic Period in Ile-Ife because archaeological evidence revealed that there was already a complex social structure in place at that time that included craft specialization.

Overview of the Chronologies of Ile-Ife

The occurrence of abundant material culture of different kinds has enhanced the works of scholars in anthropology, archaeology, history, art history, and sociology in understanding the cultural traditions and social complexity of Ile-Ife. This is mostly true in terms of establishing cultural sequences through the interpretation of material culture. The rest of this chapter discusses the periodization and the cultural periods in Ile-Ife. While table 2.1 presents the calibrated radiocarbon dates from previous archaeological investigations in Ile-Ife, Table 2.2 summarizes different periodizations that scholars have developed for Ile-Ife history, including the periodization I adopt in this dissertation.

Excavator	Sites	C14 Dates	**2 Sigma Calibrated Age 95%***
Ekpo Eyo	Odo Ogbe	855±95 YBP (I.4670) 320±95 YBP (I.4669)	AD 995 - 1292 AD 1416 - 1630
	Lafogido	840±95 YBP (I.4911)	AD 1014 - 1380
Peter Garlake	Woye Asiri	785±75 A.D (N 1688) 670±75 A.D (N 1685) 815±85 A.D. (N. 1687) 545±85 A.D. (N. 1689) 175±85 A.D. (N. 1686)	AD 1042 - 1386 AD 1221 - 1416 AD 1025 - 1379 AD 1273 - 1616 AD 1522 -
	Obalara	760±85 A.D (N. 1392) 580±60 A.D (N. 1391) 625±75 A.D. (N. 1393) 480±95 A.D. (N. 1390)	AD 1044 - 1396 AD 1290 - 1432 AD 1265 - 1431 AD 1295 - 1635
Frank Willett	Orun Oba Ado	1390±130 YBP (BM 265) 1150±120 YBP (BM 2114) 1150±120 YBP (BM 2115) 960±130 YBP (BM 264) 1010±150 YBP (BM 2116)	AD 389 - 950 AD 653 - 1151 AD 653 - 1151 AD 777 - 1277 AD 694 - 1270
	Ita Yemoo	1100±120 YBP (M2121) 790±130 YBP (M259) 480±100 YBP (M2117) 990±130 YBP (BM 261) 800±200 YBP (M 2119) 890±130 YBP (BM 262)	AD 674 - 1160 AD 995 - 1410 AD 1295 - 1635 AD 770 - 1271 AD 729 – 1474 AD 880 - 1389

Table 2.1: Previous Radiocarbon Dates from Ile-Ife. *All dates calibrated with Oxcal 4.2, IntCal 13.

Authors	Periodization
Willet (1967)	Pre-classical- prior to 12^{th} c, AD
	Classical - 12^{th}–15^{th} c. AD
	Post-classical - 16^{th} c. AD onward
Eyo (1974a)	Pre-pavement - prior to 11^{th} c. AD
	Pavement - 11^{th}–15^{th} c. AD
	Post-pavement – 16^{th} c. AD onward
Drewal (1989)	Archaic - prior to 9^{th} c. AD
	Pre-pavement - 9^{th}–11^{th} c. AD
	Early pavement - 11^{th}–13^{th} c. AD
	Late-pavement - 13^{th}–15^{th} c. AD
	Post -pavement - 15^{th}–17^{th} c. AD
	Stylized humanism – 17^{th} c. AD onward
Ozanne (1969)	Early - prior to 10^{th} c. AD
	Medieval - 10^{th}–17th c. AD
	Modern - 17th c. AD onward
Horton (1992)	Phase 1 - 10^{th}–15^{th} c. AD
	Phase 2 - 15^{th} c. AD onward
Ogundiran (2003)	Archaic - 400 BC–5^{th} c. AD
	Early formative - 5^{th}–8^{th} c. AD
	Late formative 9^{th}–11th c. AD
	Classical - 11^{th}–15^{th} c. AD
	Intermediate – 15^{th}–17^{th} c. AD
	Atlantic – 17^{th} c. CE onward
Blier (2014)	Pre-florescence - prior to 13^{th} c. AD
	High florescence- 13^{th}–14^{th} c. AD
	Late florescence - 14^{th}–15^{th} c. AD
	Post florescence – 15^{th} c. AD onward
Adopted Periodization	Period I - prior to 10^{th} c. AD
	Period II - 10^{th}–16^{th} c. AD
	Period III – 16^{th} c. AD onward

Table 2.2: Various periodization approaches to the archaeology of Ile-Ife.

Based on the examination of Ile-Ife bronze figures and terracotta, Fagg and Willett (1960: 33) have suggested that the classical period in Ile-Ife must have flourished prior to 14th century. Fagg and Willet (1960) propose three periods for the Ile-Ife sequence: Pre-classical, Classical, and Post-classical. The 'Pre-classical' refers to the period prior to the making of bronze object and potsherd pavements in the 12th century. The 'Classical' period between the 12th and 15th century, is associated with the flourishing of Ile-Ife as a polity, represented by consistent artistic styles and extensive potsherd pavements. Finally, the 'Post-classical' period was a time of decline of the classical style in the material culture (Willett 1967; Garlake 1974, 1977). The major shortcoming of this periodization strategy designed by Fagg and Willett (1960) is that it focuses extensively on Ile-Ife artworks at the expense of other archaeological materials. It also aggrandizes the period between the 12th and 15th centuries, overlooking the period before and after this "classical" period.

For Ekpo Eyo (1974), the term "classical" overlooks the uniqueness of each stage of Ile-Ife's cultural traditions. Eyo retained Fagg and Willett's chronological framework, but substituted the labels, instead using the term "classical" with new names emphasizing the occurrence of potsherd pavements. He therefore proposed a pre-pavement, pavement, and post-pavement period to describe Ile-Ife's cultural sequence. Eyo (1974b) argues that since pavements are a unique Ile-Ife tradition, they best reflect its socio-historical development rather than the tern "classical," which has its origin in the archaeology of the Greeks and Romans. However, the occurrence of pavements across Ile-Ife and Yorubaland belong to a wide variety of time periods; thus the pavements may not be a sound basis for periodization.

Ozanne (1969) offers another chronological scheme for Ile-Ife occupation based on his archaeological survey of the Ife walls. He outlines three periods in the development of Ile-Ife: early, medieval and modern. Unlike Fagg and Willet (1960) and Eyo (1974b) who do not provide a definite time period for the start of the pre-classical and pre-pavement periods, Ozanne (1969) suggests a date of the mid first millennium B.C. for early Ile-Ife. For Ozanne (1969), early Ile-Ife spanned from the 6th century BC to 10th century AD, characterized by scattered clusters of small settlements. The idea of early Ile-Ife being composed of hamlets is supported by the oral traditions of Ile-Ife. The 'medieval' period of Ile-Ife spans from 10^{th} through 17^{th} centuries and is characterized by walls without ditches with few additional loops. During the 'modern' period (beginning in the 17^{th} century), Ile-Ife's walls take on a new layout as ditches and wall loops are added. Although Ozanne's approach seems effective in understanding the formation and expansion of Ile-Ife as a city state, the study did little to provide information on how the construction and changes in the size and pattern through time impact on other aspects of the city, such social relations, political systems, economic activities, and religious beliefs.

Focusing on the arts of Ile-Ife, Drewal (1989) was the first to propose more than three periods for Ile-Ife's history. He outlined five eras: the archaic (pre 9^{th} century), the pre-pavement (9^{th} – 11^{th} centuries), early pavement (11^{th} – 13^{th} centuries), late pavement (13^{th} – 15^{th} centuries), and post pavement (15^{th} – 17^{th} centuries). According to Drewal (1989: 46), during the archaic period, Ile-Ife craftsmen made minimalist stone monoliths similar to the monoliths from Opa Oranmiyan (Oranmiyan staff) and the Idena figure (Drewal 1989: 49 - 51). Drewal believed that the combination of stone and iron in early Ile-Ife artworks were an indication of transition from Neolithic to an Iron Age technology (Drewal 2010:83). This conclusion is at best speculative since no radiocarbon date is associated with any of the stone figures in Ile-Ife. Also the stone could have been worked in later centuries when ironworking was already in practice.

By the 9^{th} – 11^{th} century, Drewal (1989: 46) argues that artworks in Ile-Ife included stylized pieces of stone and terracotta. Between AD 1000 and 1200, elaborately-decorated pavement sherds and stones rendered in a style of refined idealized naturalism became widespread. The expressive naturalism in Ile-Ife artwork continued to AD 1400 and by AD 1600 there was increasing stylization of art moving away from the naturalism of the past (Drewal 1989: 46). In the periods between the 11^{th} and 17^{th} centuries potsherd pavements were an important feature. Similar to Eyo, Drewel considers potsherd pavements important for dating because they reveal a glimpse of how the border between the mundane and the sacred domains were given spatial expression. Examination of pavements and the associated materials at Woye Asir and Obalara further supported Drewel's claims about sacred space (Garlake 1974, 1977). Again, Drewel's scheme is exclusively art-oriented, providing detailed information on artwork and its differentiation in style and material, but his scheme lacks critical engagement with archaeological data.

Horton's (1979, 1992) research on "economic Ile-Ife" offers a clearer understanding of how cultural complexity in early Ile-Ife emerged. Horton (1979, 1992) proposes two phases for Ile-Ife: phase one from AD 900 to 1500 when Ile-Ife was growing and manifested a diverse economic system and phase two which marked the decline of complexity in Ile-Ife beginning in AD 1500. Horton argues that changes in regional and interregional trade accounted for the decline of Ile-Ife, and that "it was the growth and decline on the economic plane that produced growth and decline on the political and cultural planes" (Horton 1992: 123, 140). Although Horton's argument is important in that it focuses on the particular kinds of complexity evident in ancient Ile-Ife, it remains speculative until sufficient archaeological data can be marshaled to support his claims.

Ogundiran's (2003) synthesis of archaeological, ethno-historical, historical, and oral traditional data reconstructs the processes that culminated in the cultural complexity in Yorubaland in the 12th through 19th century AD. Ogundiran (2003: 38) traces the beginning of this process back to the 6th century BC in Yorubaland with its foundation in Ile-Ife. He describes six periods: archaic, early formative, late formative, classical, intermediate, the Atlantic (Ogundiran, 2003: 38-46). Ogundiran (2003: 27) argues that pre-11th century periods mark the emergence of Ile-Ife as a city-state and pioneer of political structure and ideology that defined the worldview of the Yoruba and Edo-speaking people.

Suzanne Blier (2014) recently provided a chronological sequence for Ile-Ife. Focusing on artworks their interpretation through oral traditions, she uses the word "florescence" to describe cultural development in early Ile-Ife. Blier (2014: 44) suggests that the florescence represents the period of "cultural flowering" in Ile-Ife's major artistic and cultural innovation. She proposes three main periods: pre-florescence, florescence, and post-florescence. According to Blier (2014: 44) the florescence era began in the 11th century, marked by roulette and cord decorations. She argues that art production did not emerge until the middle of the 13th century AD and lasted till the mid-14th century AD, the period she refers to as the "high florescence era" (Blier 2014: 44). Although Blier (2014) provides an innovative approach to the interpretation of Ife arts and their development, her argument that the Ile-Ife "florescence" period only emerged in the 13th

century should be reconsidered since archaeological evidence from Ile-Ife has yielded materials that suggest florescence occurred at least one or two centuries earlier.

Many scholars have uncritically adopted Fagg and Willett's (1960) proposal that identified Ile-Ife's classical era around the 12^{th} century as the beginning of complexity in early Ile-Ife. Although Drewal's (1989) and Ogundiran's (2003) periodizations extend back to the first millennium B.C., they are limited by the lack of archaeological evidence from Ile-Ife. Although Drewal (1989: 46) tries to draw similarities between Ile-Ife's pottery forms and decorations with that of 1000 B.C occupations of Iwo Eleru in Ondo state (southern Nigeria), the evidence is too meager for a comprehensive reconstruction of first millennium BC Ile-Ife. In general, studies of the chronological sequence for early Ile-Ife lack archaeological data.

In the section that follows, I discuss the cultural historical traditions of Ile-Ife, from its earliest time to the time of its decline. This discussion is based largely on the available archaeological, historical, and oral traditional records. Since most of the chronological sequence given by scholars mentioned above overlap, I adopted three periods that best reflect the state of the archaeological, historical, and oral traditional evidence for early Ile-Ife. For the purpose of the discussion here, I identified period I to be the time prior to the 10^{th} century. We have very limited archaeological evidence for this period. However, historian have made some postulation about the early Ife communities that made have existed during the period I. Period II spanned between 10^{th} – 16^{th} centuries – a time of transformation in Ile-Ife complexity and the emergence of sophisticated craft production. During the period III (Post 16^{th} century), the complexity of Ile-Ife began to wane and other centers in the Yoruba region assumed political and economic power. I now turn to discuss each of these periods in detail.

Periodization of Ile-Ife Prehistory

The Early Phase Of Ile-Ife Occupation: Pre-AD900

Scholars have referred to Ile-Ife as the place of the beginning of urban conglomeration in Yorubaland (Johnson 1921; Willet 1967; Ozanne 1969; Eyo 1974, 1977; Eluyemi 1987; Magbogunje 1962; Adeniran 1992, Obayemi 1976, 1992). The existing archaeological and historical sources suggest that cultural complexity emerged in Yorubaland in the 10th century AD. In this period, there was a transformation in the sociopolitical organization of the Yoruba, centered at Ile-Ife (Ogundiran 2003: 43-44; 2005: 143). Social complexity is earlier in Ile-Ife than anywhere else in Yorubaland, although limited archaeological evidence has shown the possibility that socially complex societies in the Esie and Ijebu regions of Yorubaland might pre-date that of Ile-Ife (Obayemi 1982; Onabajo 1988; Momin 1989; Aleru and Adekola 2008).

This early period, however, is generally lacking in archaeological evidence, and most of what is known comes from oral traditions documented in historical records. Eluyemi (1975) has identified and explored three sources of oral tradition for Ile-Ife: priests and family heads, chiefs, and elders. The knowledge of events in Ile-Ife during the pre- 1000 AD period had greatly benefited from these sources (e.g. Johnson 1921; Adediran 1992; Obayemi 1992; Akinjogbin 1992; Akinjogbin and Ayandele 1980). However, these sources are not trustworthy for the reconstruction of the remote past; it is well understood that as oral information is passed down through the generations, it tends to lose its accuracy. However, this is not to say that oral sources are totally unreliable; in a number of contexts, oral traditions have proven an effective source for site identification and historical reconstruction in Africa. It has been proven that toponymy and *oriki* (praise songs) are some of the most viable forms of oral traditions for historical reconstruction (and site identification) in Yorubaland (Eluyemi 1975; Momin 1989; Ogunfolakan 2002).

According to oral traditions, human settlement in Ile-Ife during the pre-10th century AD was comprised of 13 scattered villages and hamlets. Oral traditions name the village settlements: Ido, Ideta Oko, Ilora, Iloromu, Ijugbe, Imojubi, Iraye, Iwinrin, Odun, Oke Awo, Oke-Oja, Omologun, and Parakin. However, these have yet to be thoroughly investigated despite Eluyemi's (1975: 121) effort to plot their locations. Each of these settlements is believed to have been further divided into quarters with a "priest king or chief priest" ruling over it. The settlements contained different lineages and the ruling system was flexible and lacking centralization, implying that there was "idea of mutual cooperation" among the clustered villages (Adeniran 1992: 80-81). This may have been a confederacy with a "loose political alliance short of political integration, with no central chieftaincy hierarchy, powerful royal dynasties, centralized governments, or urban capital" (Ogundiran 2003: 42). However, Obayemi (1992: 56-7) has argued that some of these communities already had hierarchical political systems with the crown as a symbol of royal office.

According to the archaeological evidence and oral traditions, it is during the 10th century AD that sociopolitical hierarchy emerged, symbolized by crowns and beads; this is a time of transforming political structures and centralization. Historians have suggested that the foundation of complexity in Yorubaland was established by the Oduduwa dynasty during a period of state formation and political upheaval (e.g. Akinjogbin 1992; Adediran 1992). Oral traditions tell of a power struggle between the political loyalist of the early settlements and the followers of Oduduwa who believed in his centralized system of government. The Oduduwa faction was victorious, taking over the baton of leadership, bringing settlement under one ruler, and reorganizing the Yoruba kingdom centered in Ile-Ife (Akinjogbin and Ayandele, 1980; Olomola, 1992). This new political system was centered on a divine kingship system that understood the king as holder of both spiritual and political powers. The power of the religious and political elite was represented in the sculptural industry in Ile-Ife. This period, when social complexity was emerging in Ile-Ife, is less well understood archaeologically than that of the classical period.

The early centuries of Ile-Ife are elusive in its archaeological record. There is some evidence of early occupations at Ile-Ife. Charcoal samples from the excavations on the Obafemi Awolowo University campus have provided a date of 350 BC (Ozanne 1969: 32). The site from which this sample was excavated is believed to be Omologun, one of the thirteen villages of early Ile-Ife (Olomola, 1992: 55). Although Eluyemi (1975: 117) has reported to have identified and plotted the sites of these villages, there has never been follow-up research to corroborate his claim. In other words, no archaeological investigation had been carried out on any of the autochthonous settlements. The excavation by Folster was never fully published and the 410 BCE date has been generally regarded as a problematic, isolated date because it lacks crucial supporting evidence (Willett 2004).

A radiocarbon date of cal AD 560-940 from the site of Orun Oba Ado, located in the center of Ile-Ife close to the palace, has been considered secure date from Ile-Ife. This date, according to Willett (1970: 323) establishes an early occupation period for Ile-Ife, a claim made by oral traditions. Tradition links the Orun Oba Ado site to the Benin dynasty as the place where the heads of Benin kings were buried; however, the radiocarbon dates suggest an occupation that predates even the founding of the Benin dynasty. Although we know that early Ile-Ife is dated to the first millennium AD, we do not have a firm idea of the material culture that was prevalent at that time. This is an area where most of the archaeological investigations in Ile-Ife, especially those during the early period of its occupation, are seriously lacking. Research that focuses on understanding the material culture of Ile-Ife during this period should be of high priority.

Additional archaeological evidence that points to Ile-Ife having been occupied in the pre 10^{th} century era includes evidence from the city walls. Ozanne (1969) suggests the 10^{th} century as the beginnings of a centralized political structure, based on radiocarbon dating. The construction of the medieval wall overlapped with the period of the disintegration of Ile-Ife's "loose sociopolitical confederacy" as well as the configuration of the hierarchical political system centered on elaborate rituals involving large numbers of glass beads from an industry set up to service the elite in the royal personage (Eluyemi 1987: 200; Ogundiran 2002: 433, 2005: 149). This foundation set in the later first millennium AD become more sophisticated in the centuries that follow.

Period II: The Era of Transformation, AD 900–1500

The period between the 10^{th} and 16^{th} centuries is well documented in the archaeological record of Ile-Ife. Archaeologists, anthropologists, historians, and art historians have agreed that this period was characterized by increased socio-cultural complexity that began in the late first millennium AD. These transformations are amplified with evidence of craft specialization in glass beads, terracotta, bronze, pottery, and potsherd pavements. During this period, Ile-Ife witnessed tremendous settlement expansion, perhaps due to population increase. Ile-Ife also grew in political and ritual powers such that it began to dominate other politically- or religiously-weaker settlements, as well as tighten its security (Ozanne 1969). During the period the political structure was federated/centralized with the political elite in charge of the economic and religious life at Ile-Ife. Although it is still uncertain when and how this transformation began, the archaeological evidence at our disposal gives a clear picture of the complexity at Ile-Ife between 10^{th} and 16^{th} centuries AD.

Archaeological evidence in terms of significant glass bead production and the fabrication of copper alloy objects of political significance during this time suggest that political, economic, and religious powers were bestowed to the elite, making commoners subservient to the elite's rule. Most of the copper alloy figures depicted important people, such as the king and queen, and other people of political or religious significance. However, it is important to note that religion was a major influence on other institutions. Ogundiran (2003: 45) states that "royal rituals became the core of public participation and the institutions of these rituals became sources of patronage of arts and religious and social values." Several cults were instituted and shrines and temples were built across the city. Archaeological investigations have revealed some shrines and temples dated to 10^{th}–16^{th} century (Garlake 1974, 1977; Eyo 1974).

The cultural transformation in Ile-Ife between AD 900 and 1500 is evident in the material culture and technology of this period. Archaeologically, this revolution in material life at Ile-Ife was reflected in sophisticated architecture with pottery pavement, increases in glass bead production, detailed naturalistic human art in bronze and copper, iron smelting, manufacturing of special pottery for ritual and spiritual ceremonies, and increased ritual practices. During this period, glass beads became a major trade item and Ile-Ife a commercial center where objects were traded (Willett 1977; Horton 1979; Adediran 1992: 92). Beads were traded through long distance trade, and also sold and distributed to other parts of the Yoruba region as objects of political and religious power (Ogundiran 2003: 57). Ile-Ife beads were also displayed as status symbols of power and authority. The bronze and terracottas from Ile-Ife are mostly decorated with beads around their neck, wrists, and ankles, reflecting kingly status (Willett 1967: 105-6, Eluyemi 1975).

Beyond bead manufacture, other forms of craft specialization were developed between the 10th and 16th centuries: including sculptural specialization in bronze, terracotta and stone. Several craft objects have been either excavated or collected from many areas around Ile-Ife dated to this period. The technology of bronze casting proliferated in Ile-Ife between the 12th and 15th centuries (Willett 1967, 1970). Ile-Ife bronzes were produced through the lost wax technique. The technique was said to have diffused into other Yoruba-Edo speaking towns during the florescence of Ile-Ife. This is particularly evident in Benin bronze/brass casts. Willett (1967), Connah (1969), and Garlake (2004) have discussed the procedure of loss-wax technique at length.

As discussed above, Ile-Ife bronze figures suggest a centralized political system because many represent royal figures or objects of power of religio-political office. Among the materials recovered from Willett's (1959) excavations in Ita Yemoo was a pair of bronze figure possibly representing an Oni and his Queen and staff or mace in bronze, featuring an adornment of human heads.

Archaeological evidence has shown that, by the 10th century AD, Ile-Ife was under the control of a powerful, centralized, political and religious authority. The copper alloy object excavated by Willett at Ita Yemoo, which consist of scepters with a human head and some with gagged humans all dated to the 14th and 15th centuries, suggesting the dominance of the elite (Willett 1977; Drewel 2009: 116). A parallel can be drawn from the ethnographic present about the significance of scepters in Yorubaland. Various ethnographic work (e.g., Drewel 1989; Aremu 2009) have demonstrated that in the Yoruba tradition a mace or scepter is given to king or chiefs after coronation or initiation into a royal cult. The staff symbolizes political and ritual authority encoded in *ase* (potent power). In the Ogboni cult (a secret society where some of the members are priests and priestesses of gods and deities), for example, a staff is synonymous with *edan ogboni* (Ogboni's staff). The members are responsible for social and political order and ritual practice in a settlement. The Ogboni select, install, and bury kings and also judge and punish criminals (Drewel et al. 1989: 39). Among other things, edan ogboni symbolizes power and authority (Aremu 2009). It is possible that the scepters from Ile-Ife served similar functions. In Yorubaland, some deities are associated with bronze or brass staffs as symbol of their authority. The staffs are either placed in their shrine or associated with cults.

The transformation that heralded the period between the 10th and 15th centuries is evident in the architecture of Ile-Ife from that time. There was increasing interest in putting aesthetic touches on buildings, such as potsherd discs that date to this period (Garlake 1977). Garlake (1977) suggests that potsherd discs were used as facings on walls or columns at Woye Arisi. However, potsherd pavements remain the most significant archaeological evidence of complex architectural design in early Ile-Ife. The proliferation of pavement construction during this transformative era also suggests a complex religious ideology, especially ritual and political authority. The presence of pots without bottoms as part of the structure of the potsherd pavement at Woye Asiri and Obalara as well as other archaeological sites in Yorubaland (Garlake 1974, 1977; Ogunfolakan 1994) indicates "routes" connecting the Yoruba world with the ancestral underworld. The altars also served as place of sacrifices, offerings, and libations (Garlake 1974; Ogundiran 2003: 51).

The domination of Ile-Ife religious influence in the Yoruba region is evidence by the proliferation of shrines, groves, burials, and temples in Ile-Ife, most of which date to between the 11th to 15th centuries. The excavations in Odor ogle and Algoid are good examples (Eyo 1974a). At Odo Ogbe, the excavations exposed a burial chamber with poorly preserved human skeletons. Some pots were also recovered in association with worn pebbles. Eyo (1974a: 109) interprets this to be evidence of "pit and pot" burial practice. Eyo (1974: 109) defines the pit and pot practice as a process of marking a burial after the pit has been filled with earth. This pit and pot burial practice has been criticized not to be a common practice in Yorubaland (Agbaje-Williams 1991: 10). However, the excavation revealed a burial chamber, which later becomes a shrine to the water goddess with a date of AD 1095 (Eyo 1970, 1974a: 105-6).

At Lafogido, the excavations yielded terracotta heads found in situ, carefully laid in a specific arrangement, suggesting primary context. The material excavated from this site includes terracotta heads depicting antelope, ram, bush pigs, elephants, and chameleons, with a fragment of human arm and a potsherd pavement. Eyo (1970: 47) argues that the terracotta would have been used as sacred furnishing, suggesting royalty. There are dozens of other archaeological shrines or groves in Ile-Ife that have yielded offerings and ritual objects in terms of terracotta, votive pots and pavements. This includes Osangangan, Obameri, Ita Yemoo, Woye Asiri, and Iwinrin among others (Willett 1967; Myers 1967; Eyo 1970; Garlake 1977).

The period between the 10th and 15th centuries may have also witnessed significant pottery production. Like brass casting and glass bead making, the ruling political class may have been in control of the pottery industry. Different types of pottery materials were made for different purposes, including ritual, domestic, and industrial uses. One oral tradition speculates that potsherd pavements were produced through force and/or coercion. Oral traditions state that during one female Ooni's (Luwo) reign, she ordered that her palace and other public places be paved. Luwo was described as a "strict disciplinarian who made the people to work very hard and punished laziness severely" (Fabunmi 1969: 23; Ogunfolakan 2001).

By the end of the 15th and early 16th centuries, Ile-Ife had become a center of strong politico-religious power centered on kinship, and the elite were in control of a major economic entrepot. Ile-Ife's complexity at this period spread beyond its geographical boundary. Its politico-religious influence can be seen in the material culture recovered in other settlements outside the Ile-Ife core area, dated to between the 13th and 18th centuries. For example, evidence of Ile-Ife material was found in early Osogbo, Ikirun, Ijebu-Ode, Owo, Ilare, Ede-Ile, and other Yoruba-Edo regions, as well as farther to the west in the Dahomey region, in what is now the Republic of Benin and up to Togo (Willett 1967: 103-4, 1973: 132; Eyo 1974b; Ogundiran 2000, 2002, 2009, 2014). These artifacts "suggests the primacy of Ile-Ife-Ile in regional interactions between AD 1000 and 1500" (Ogundiran 2005: 150).

Ile-Ife was not only a trend setter in art and architecture, which were emulated throughout the Yoruba region and beyond (Hull 1976: 3), but also established the foundation for hegemonic states such as Old Oyo to the north and Benin to the southwest. The foundation of these hegemonic polities replaced Ile-Ife politico-religious ideology through military expansion and domination (Ogundiran 2003: 60). This militarization was most pronounced in the late 2nd millennium AD.

By the end of the 15th century, Ile-Ife had developed robust networks with the outside world through long distance trade. This was evident in the economy of Ile-Ife. Although agricultural practices developed in the early periods persisted, the products became the commodity of long-distance trade. It has been suggested that one of the important products coming out of Ile-Ife during this period was kola nut (Shaw 1981:122). The centrality of kola nut to the Ile-Ife economy and its use as a source of wealth for the elite has been well documented (Horton 1992). According to Horton (1992: 127) Ife poems describe a dynastic founder "as a trader whose wealth was derived from the export of kola-nut, and who brought numerous horses into Yorubaland in return." Although the figure in the poetry might not be directly linked to Ile-Ife, Horton states that the poem gives provides support this that kola nut was important to early Ile-Ife (Horton 1992: 127). The implication of this is that during AD 1000-1500, Ile-Ife engaged in the web of the trans-Saharan trade network. The location of Ile-Ife at the northern edge of the forest and proximity to the Niger would have availed Ile-Ife of the opportunity to participate in north-south trade networks (Shaw 1973: 232).

However, recent chemical analyses of artifacts such as beads and copper alloy materials from Ile-Ife have revealed substantial additional evidence of Ile-Ife's interaction with the external world. While raw material for glass bead production was sourced locally, metal and copper alloys were sourced from outside. Although the chemical analysis of Ile-Ife glass beads suggest a local source of the raw material or other sources somewhere in southern Nigeria near Ile-Ife (Lankton et al. 2006), analysis of the lead isotopes in Ile-Ife copper alloys shows that by the 2nd millennium AD Ile-Ife likely sourced its raw material for brass sculptures from Northern Europe across the Mediterranean, through the trans-Saharan trade route (Willett and Sayre 2006). Ile-Ife alloys are usually much lower in tin and higher in zinc and lead. The Ile-Ife isotope ratio suggests the French Massif Armoricain ore field or the NE European ore mineralization zone as the center of the supply of Ile-Ife metal (Willet and Sayre 2006: 64-6).

Period III: Ile-Ife After 1500 AD

There were many reasons why Ile-Ife's political influence waned after the 16th century: the formation of new polities with different political ideologies centered around militarism and a shift to commerce more centered at the coasts (Horton 1992). The decline of Ile-Ife complexity as reflected in its craft production was in part a result of the massive population movement out of Ile-Ife (Horton 1979). Although there was continuity, to a certain extent, in Ile-Ife's pottery tradition (Garlake 1977), the production of humanistic terracotta and bronze figures declined. Terracotta production and the making of ritual or ceremonial vessels with elaborate iconographic decoration proliferated among newly-formed polities in Yorubaland, such as Owo and Ijesa (Eyo 1976; Willett 1969; Ogundiran 2002). Likewise, the center of bronze and brass casting shifted to Benin. Horton (1992: 136) argues that, by the 17th century, Ile-Ife was one of the smaller political units in the Yoruba region much diminished from its great wealth and military power of the past. Horton (1992) further argues that economic decline was the major cause of the dwindling political power of Ile-Ife.

This situation at Ile-Ife after the 16th century can be observed in the archaeological data. Dates from Ita Yemoo, Odo Ogbe, Obalara, and Woyo Asiri show that Ile-Ife flourished between the 10th and the 15th centuries, and by the mid-16th century the laying of potsherd pavements, the manufacturing of elaborate pots and terracotta, the casting of bronze, and the smelting of iron came to a stand-still. After this period the material culture of classical Ile-Ife ceased to occur in Ile-Ife deposits (Willet 1967: 150).

Scholars have proposed different scenarios to account for the decline of classic Ife. Oral traditions point to mass emigration from Ife at the time of the city's dwindling political power on the one hand, and the increasing drive for founding new polities on the other hand. Either way, mass migration would have decimated both the economy and the military strength of Ile-Ife. The decrease in the military personnel in the post-classical era may have instilled fear in the people. The fear of attack in Ile-Ife was reflected in the repair of the modern wall, perhaps to strengthen the security of the city. Describing the defensive aspects of the later Ile-Ife wall, Ozanne (1969: 37-8) states that the wall of modern Ile-Ife was more pronounced with shaper profile and ditch on the outside. The restructuring of the Ile-Ife medieval earthwork from possibly a territorial maker with little or no defensive devices to a "materiality of anxiousness and worry" (Fleisher 2009) indicates weaknesses in its political legitimacy during Period III.

The migration of people out of Ile-Ife may have also led to an economic crisis and its eventual decline as a political and economic power. If the military was a significant part of the government, it is impossible that craftsmen too formed a substantial part of the group that left. The effect of this on the economy would have been low productivity, inability to meet up with the supplies, and low revenue. Horton (1992) has argued that the inability of Ife to maintain its economic posterity may have contributed to its decline.

Beside arguments about migration and its effect on classic Ile-Ife, scholars have also suggested other possible reasons for Ile-Ife's decline. Since decrease in a particular object that defines a society at a particular time can be associated with the decline in significance of the society, Blier (2014) gives two possible explanations of the disappearance of the classic Ile-Ife artworks in the post-classical era. First, she suggests that the reigning Ooni might have put all the craftsmen in Ife to death prior to his own death. Blier's second suggestion is the likelihood that the "black death" – the 14th century pandemic that killed almost 60% population of Europe – affected Ife and resulted into its decline. These assertions are not supported by archaeological and historical data that are currently available. No archaeological data suggest massive death in Ile-Ife or any other Yoruba polity at this time. Rather, this period witnessed settlement expansion and the formation of new Yoruba polities across the region (e.g., Usman 2012). At the same time, more Ife-styled artworks began to appear in other Yoruba communities. The proliferation of Ife art in other places supports the migration hypothesis more than Blier's arguments. However, it should be stated that we do not have enough knowledge of Ile-Ife archaeology during this period to make any firm conclusions. A future focus of archaeological investigation on sites of Period III in Ile-Ife and its surrounding countryside would create a clearer path to understanding the events that unfolded in post-16th-century Ile-Ife. I make a very preliminary effort at addressing this issue in Chapter 5 when I discuss the relationship between classic and 17th-century Ile-Ife pottery.

Concluding Remarks

Available archaeological records have shown that Ile-Ife has been the site of more archaeological excavations than many other sites in Yorubaland, and by extension Nigeria. These multiple excavations at Ile-Ife are, in part, due to the early discovery of the city's antiquity during the colonial era in Nigeria. The government of the colonial period was interested in the collection and curation of antiquities for the unification of Nigeria. This effort to collect antiquities across the nation explains why most of the early archaeological expeditions in Ile-Ife focused on particular art objects. This chapter has discussed how the artwork-oriented archaeology of Ile-Ife, coupled with oral traditions and historical sources, has been used to reconstruct cultural phases of the urban center.

Our knowledge of the cultural history at Ile-Ife is limited to the classic era, a period that begins in the late 10th century. Archaeological, oral traditional, and historical records have revealed that our understanding of the past life-ways of Ile-Ife inhabitants is based on elite narrative because of the disproportionate attention paid to objects of power, such as the paraphernalia of royalty. The period also witnessed the construction of the city wall, which was the hallmark of a new urban landscape (Ozanne 1969) as well as the construction of pavements and the intensification of craft specialization (Ogundiran 2005: 150). At the onset of the 16th century, when newly formed polities in the northern Yorubaland (Old Oyo) and further southeast (Benin) reached their maturation, Ile-Ife's power began to dwindle. However, it upheld its symbolic significance as the birthplace of the Yoruba people. The retention of this ritual power enabled Ile-Ife to continue to function as a powerful religious center and to maintain its dominance of religious and ritual affairs of the hinterland and other outlier communities (Shaw 1981:131). The function of Ile-Ife as the religious and ritual hub of the Yoruba people defines Ife's urbanism, which is strongly associated with the long-term monopoly of important crafts – especially glass beads, which were are a symbol of politico-religious and socio-economic status in Yoruba traditions.

With regard to the intensification of craft production during the classic Ife, scholars have studied the technology of copper alloy materials from Ife in greater detail than they have glass materials (e.g., Werner and Willett 1975; Willett and Fleming 1976; Willett 1977; Willett and Sayer 2006). However, there is now increasing attention paid to glass bead production. In order to further our understanding of the importance of glass and glass beads in Ife, we need to address a number of questions: If glass beads were important objects in classic Ile-Ife what form of technologies were involved in their production? What were the processes of production and distribution? How and where were the raw materials sourced? And of what significance was the glass bead production in the urban center and the outlier settlements? These questions are addressed by this dissertation.

Chapter Three

GLASS PRODUCTION IN ANCIENT SOCIETIES: CHRONOLOGY, PROCESS, RAW MATERIALS, AND CHEMICAL COMPOSITION

Introduction

A core aspect of this dissertation is the analysis and evaluation of glass production debris from Igbo Olokun in an attempt to discern the technological processes involved. As background, this chapter reviews the various steps in the production process and the raw materials used in creating various early glass recipes in different areas of the Old World. The high alumina recipe common at Igbo Olokun and other Ile-Ife sites differs significantly from any of these recipes, raising the question of local primary production (Lankton et al. 2006; Freestone 2006). Primary glass production ('glass-making') is defined as the making of glass from raw materials. Archaeological evidence of primary glass production is usually uncommon. The lack of direct evidence of primary production workshops is, partially due to the ephemeral nature of the materials used in glass production compared to those used in metal production (Rehren 2013 Personal Communication). Also considering the intricacies and complexities involved, primary glass production was a rare specialized process. As a result scholars have suggested that "only a few primary glass production sites existed" (Smirniou and Rehren 2011:59).

Secondary glass production is also known as 'glass working'. Here, the craftsman fabricates different objects out of already made glass, although occasionally glass can be remelted and colorants added at glass-working workshops. Unlike glass-making, glass-working does not usually require high temperature. While a glass-working workshop can co-exist with a glass-making factory (Henderson 2000; Smirniou and Rehren 2011:59), it can similarly operate independently either in same vicinity or faraway in entirely different region. In fact, a glass-working workshop can be within a household. The flexibility in the operation of glass-working and, perhaps but not always, the small size of the required space is a factor that allows wider spread of secondary workshops compared to primary production centers.

Whether primary or secondary glass production sites co-exist or not, there are certain types of archaeological evidence that suggest their presence: furnace remains; apparatus/tools used in production (e.g. crucibles, ingot molds); manufacturing/ industrial waste (e.g. gall, glass slag, raw glass; glass chunks, glass canes/rods, glass drips); availability of raw materials within the workshop's vicinity (mostly siliceous and alkali materials); preformed, finished, or unfinished products (e.g. frit, semi-finished glass, ingots, vessel fragments, glass beads, malformed products); and the density of such materials in the archaeological record (e.g. Oates et al. 1998; Brill 1988; Henderson, 1998; Oppenheim et al. 1970; Henderson 1999, 2000, 2013; Liyquist and Brill 1993, Shortland 2009; Freestone and Rosen 2000; Panagiotaki, 2008; Rehren et al.. 2001; Rehren and Pusch 2005; Pusch and Rehren, 2007; Nicholson, 2007; Tite and Shortland 2003; Jackson and Nicholson, 2007; Nicholson, et al.. 1997; Merkel and Rehren, 2007; Nicholson, 1996, Shortland and Tite, 2000; Jackson et al., 1998; Kemp, 1989; Moorey, 1994; Turner, 1956).

Not all types of evidence will necessarily be found at every site. It is only through a detailed analysis of the material and follow-up investigations that a compelling argument can be made for glass production at an archaeological site. A solid argument for the presence of a glass production workshop must be able to not only identify a primary or secondary production center, but also present a hypothesis concerning the acquisition of raw materials, the glass production procedures, the nature of the products, and aspects of the distribution and consumption of the products. A strong argument for the presence of a center of glass productions includes an explanation of the glass' entire lifecycle.

In the rest of this chapter I seek to discuss the issues relating to ancient glass production. I will begin with a brief discussion of the chronology of glass in the ancient world. The discussion on the chronology focuses on when and where first glass was invented, and how technology spread across the globe and evolved through time. I then proceed to present the processes involved in glass making as identified and discussed by other scholars. This discussion of the process of glass making is followed by an examination of the various raw materials used in glass making and their effect on the overall quality and durability of the glass product. This is followed by a discussion of the agents of coloration and opacification of ancient glass. I also discuss primary glass production in Sub-Saharan Africa. This is concern with the evidence and issues in understanding glass production in the sub-continent. Since glass beads were the main artifacts recovered from our excavations

This chapter finally considers the technology of glass bead making in ancient societies. It considers types of glass beads and the processes in making them. It should be noted that this chapter draws from existing archaeological evidence around the world, and occasionally refers to historical and ethnographic materials. Throughout this chapter references are also made to ancient societies around the globe to buttress the point on the places where particular objects or activities were found or carried out in the past.

Early Glass

Development and spread

Glass is produced by combining silica (SiO2), an alkali flux (soda Na_2O or potash K_2O) and stabilizers (calcium [lime CaO] or alumina Al_2O_3) at temperatures high enough to melt (locally up to 1675°C.). The earliest evidence of glass technology is in Mesopotamia, perhaps as early as 2300 B.C. (Moorey 1994; Henderson 2000, 2013), and certainly by 1600 B.C. (Barag 1970, Shortland 2000; Rehren and Pusch 2005). Regular production of glass at increasing scales only occurred after 1500 B.C. The development of glass was preceded by over a millennium of development of other vitreous materials, such as glazed quartz, glazed steatite, and faience. The technology of these vitreous materials is dated to between the 5th and 4th millennia B.C, in Egypt and Mesopotamia (Peltenburg 1971, Shortland *et al.* 2006). There is debate as to whether metallurgy or faience production provides the main technological impetus to the development of glass (Peltenburg 1987; Tite 1987; Bimson and Freestone 1987; Shortland 2000;

Nicholson 2007). In either case, knowledge of and experience with pyrotechnology, refractories and the control of complex chemical reactions at high temperatures provided the technical background needed for producing glass.

By1500 B.C. glass production was taking place on a large-scale throughout Egypt (Shortland 2000; Smirniou and Rehren 2011). Chemical analysis of numerous glass artifacts and production debris has revealed that production centers existed and were active both in Mesopotamia and Egypt from Late Bronze Age (LBA) through the Islamic period (e.g. Freestone et al. 2000; Henderson et al. 2005; Nicholson 2007; Push and Rehren 2007; Smirniou and Rehren 2011). Recent studies have shown that some ingredients of Egyptian glass were imported from Mesopotamia (Shortland and Tite 2000), and that Eypt was ordering glass supply from Mesopotamia (Rehren 2014). This indicates that the Near East was an important center of glass production that exported glass to many other parts of the world. For example, the studies by Panagiotaki (2008) have shown that technology of glass spread from Mesopotamia to the Mediterranean in the mid first millennium B.C. In the same period glass was being exported to as well as produced in China (Li *et al.* 2013). The Han dynasties allowed the wider spread of glass in the Southeast Asia. The rise and expansion of the Roman and the Sassanian empires in the 1nd and 3rd centuries A.D., respectively, facilitated the spread of glass to northern Europe and central Asia (Smedley and Jackson 2002). Similarly, the Near East and Southeast Asia have been considered as the sources of glass that appears in sub-Saharan Africa with increasing frequency in the first millennium A.D.

Production process

There are several steps involved in the production of glass. These include: gathering raw materials, fusion (primary production), making of colored ingots, and the fabrication of objects (secondary production). Biek and Bayley (1978:1) summarize the three major steps in glass making:

> "the first [step in glass making] was to bring the two main components silica and alkali, together at a moderate heat for some time and allow them to react in a solid state. Melting at this stage has to be avoided at all cost as it prevented proper contact, and did not allow any thorough mixing. All ancient recipes are very careful

to emphasize this vital point. The second stage was to break up this resultant 'frit' and grind it up as finely as possible to get the most intimate mixture. Finally the powder was thoroughly melted and could then be cast, moulded or drawn into objects, which were finished by annealing (gentle heating to relieve stress), polishing, cutting …"

Other researchers have divided these steps into different stages. For example Henderson (2000:38) points out five procedures: the selection and preparation of raw materials; making the glass involving fritting the raw materials; mixing the batch and melting the glass; working the glass to form the glass objects; and annealing the objects. Goffer (2007:124) describes six stages: selecting the raw materials; comminuting and mixing the raw materials; heating and melting the mixture; forming and shaping; annealing; and finishing the objects. While some of these processes are carried out only during primary production (e.g., frit production), others (forming, shaping, annealing) can also occur in secondary production workshops.

The frit derived from heating and partial fusion of the primary raw materials for glass is described by Henderson (2000:83) as a grayish granular material of sugary consistency that is full of trapped gas bubbles. In ancient grass production, fritting of raw materials allowed the removal of impurities in the form of gasses, derived from the breakdown of carbonates and sulphates, which helped reduce the number of gas bubbles in the glass melt (Henderson 2000: 38).

Frit was found in 8th–9th century deposits at al-Raqqa, Syria in association with furnace and other production debris Henderson (2000:82-3). It is not known, however, whether raw materials were fritted directly in the furnace or indirectly in some form of carrier/container. Saleh *et al.* (1972: 144) have identified rectangular crucibles from Wadi el-Natrun in Egypt dating to 30 B.C.– A.D. 359, which they suggested were used in fritting of raw material for glass production. Henderson (2000:83) has suggested that trays could have been used as vessels for fritting at al-Raqqa in Syria. Merkel and Rehren (2007:201-21) have carried out a reconstruction and experimental work on ceramic vessels that would have been used in glass making at Qantir-Piramesses in LBA Egypt. This study reveals that a significant interaction occurs between the parting layer – "calcium-rich coating … between the ceramic and the glass, and seen as non-reactive separating material" – and the glass charge, and also with the ceramic (Merkel and Rehren 2007:209, 223). Merkel and Rehren (2007:223) conclude that the result ultimately supports the model of partial melting or fritting or making of semi-finished glass.

Semi-finished glass has been a less used and less clearly defined term than frit in studies of ancient glass production. However, recently Pusch and Rehren (2007) and Smirniou and Rehren (2011) have clearly defined semi-finished glass and detailed the process of its production in primary glass workshops in LBA Egypt. They provide a three-test checklist that characterizes semi-finished glass in these workshops. These defining characteristics include the presence of significant quantities of residual quartz; the presence of a lime-rich newly formed crystalline phase; and a lower content of lime at around 3-5% (Rehren and Pusch 2007:153; Smirniou and Rehren 2011:64-66). To summarize, semi-finished glass is a partially fused glass rich in residual quartz and air bubbles. Compared to frit, semi-finished glass is glossier and requires less effort in order to be formed into an ingot. Furthermore, semi-finished glass is "always uncolored, and often appears white opaque" (Pusch and Rehren 2007:132).

The presence of semi-finished glass in an archaeological site is significant. The occurrence of semi-finished glass on archaeological sites has been suggested as "a strong indication for local primary glass making" (Smirniou and Rehren, 2011:65). It is noteworthy that both frit and semi-finished glass are uncommon on archaeological sites, even among archaeological sites with convincing evidence of glass working. The dearth of archaeological evidence of frit and semi-finished glass on archaeological sites suggests that not all ancient glass working centers would have engaged in this initial process of primary glass making. Although I agree with Freestone's (2005:3) claim that "there were a small number of primary workshops making raw glass" in antiquity, because archaeological evidence of primary glass production has come only from the Mediterranean, Near East, and Roman world (e.g. Oppenhein et al. 1970; Henderson 2000; Panagiotaki et al. 2005; Pusch and Rehren 2007; Smirniou and Rehren, 2011), it is not unlikely that other smaller glass working centers in other parts of the Old World could have engaged in primary glass production - at least on a small scale to meet their need – along side secondary glass working. Ethnographic records have demonstrated that primary glass production can be carried out concurrently with glass working in the same workshop. Identifying this type of workshop/process in the past remains a challenge for the archaeologists, however.

Following fritting and/or semi-finished glass making or what I call "pre-ingot production", comes the production of finished glass ingots from the fritted materials or semi-finished glasses. At this stage additional fluxing materials and colorant are added to the batch and melted at higher temperature. Although there are different opinions on when exactly in the production chain colorants were added (Rehren1997), Smirniou and Rehren (2011:60-61) have suggested that the stage in which colorants were added and the batch melted to full fusion is the final step of primary glass production

The archaeological record has revealed that ingot and/or glass chunks were transported and traded among many ancient societies. The transportation was mostly from primary workshop to secondary workshop or "glass studios" (Rehren and Pusch, 2007) where the ingots were further worked to fabricate different glass objects. This process included shaping, annealing, and finishing.

Forming was an important stage in glass working in antiquity because makers are deciding what to form and the amount of detail that should be used. Although the intentions of the maker are elusive in archaeological records, the techniques are often readable. Many decades of archaeological investigations of ancient technologies have revealed several techniques of glass forming including modeling, blowing, pressing, winding, and drawing. The choice of the technique of forming depends on the kind of objects to be formed and the skills of the maker. There are records that several ancient societies have used multiple techniques to form different glass objects including vessels, bangles, beads, and lamps among others.

The preferred techniques for shaping glass have changed through time. In terms of glass forming techniques in antiquity, archaeological evidence has shown that the earliest glass objects were formed using the "modeling technique." The glass was modeled around a sand-core from the mid 15th century to the 1st century B. C. in Egypt (Kunungo 2004). By the 1st century B.C., the pressing technique was introduced. Not too much later, glass-forming technique shifted to blowing. Kunungo (2004:17) has suggested that the blowing technique was first introduced in the Phoenician coast in about 1st century B.C., and later spread to the inland and became the standard technique. The introduction of blowing revolutionized the glass industry in the Mediterranean and Near East, which brought about an increase in production, innovation in color recipes, and a more diverse use of glass objects in everyday life especially in the Near East and Europe throughout the first century AD (e.g. Harden 1933:420-2; Freestone, 2006:201). In the Indo-Pacific region, drawing was a unique way of forming glass, especially in the production of glass beads spanning the last two thousand years (Francis, 2004:449). It should be stated that a detailed description of each of these methods is not within the purview of this study. However, since glass beads appeared to be the main glass object type recovered from the site of the investigation for this dissertation, I discuss in more detail the techniques associated with glass bead making in the later part of this chapter.

All the stages involved in either glass making or glass working generate different kinds of waste. Similarly different residues are also left on site or discarded for various reasons. For example, gall, frit, raw glass flakes, and "white working waste" are associated with primary glass making (Smirniou and Rehren 2011:65). Waste such as glass chunks, glass vessel fragments, cullet, drips/droplets, glass rods, collapsed tubes, and malformed glass objects among others mostly characterize glass studios (Francis 2004). The discovery of these kinds of waste in association with other apparatus used in glass production on an archaeological site suggests the former presence of an early glass industry (primary or secondary glass production). Since crucibles are common forms of apparatus found on glass making and glass working sites around the world (Rehren and Pusch 1997; Rehren 2003; Bayley and Rehren 2007; Henderson 2013: 18), it is worth considering these here in more detail.

Crucibles played a significant role in both primary and secondary glass production in ancient societies. Along with furnaces, crucibles are an essential part of all activities involving high-temperature processes in early societies; in fact, crucibles can even be used as furnaces. Because of the use of crucibles in high-temperature processes over thousands of years across the globe, Bayley and Rehren (2007:46) have described them as "truly cross-cultural artifacts." The definition of a crucible within the context of their use in glass production is a vessel made out of clay for the purpose of melting or coloring of glass batch (Rehren and Pusch 1997; Rehren 1997). Thus, they are often made of refractory material, and sometime referred to as “technical ceramic” or “reaction vessels” (Martinón-Torres and Rehren 2014; Pusch and Rehren, 2007). Crucibles occur in archaeological sites in various sizes and shapes, including U-shape (Kanungo 2004:15), cylindrical (Rehren 1997; Rehren and Pusch 2005; Pusch and Rehren 2007), rectangular (Saleh *et al.* 1972), globular (Frobenius 1913; Schildkrout 2009), and even triangular (Martinón-Torres and Rehren 2014). They can have either open or restricted orifices and a rounded, pointed, or flat base. The wall thickness also varies considerably depending on the overall size of the crucible, although the attributes of crucibles are also associated with their function.

Various studies have demonstrated that the morphology of crucibles is linked to both technical and functional related issues such as refractoriness, insulating capability, firing technique, furnace temperature and control of heat, fuel selection, air supply, and the type of substance melted in the crucible (e.g. Bayley and Rehren 2007; Martinón-Torres *et al.* 2008; Rehren 1997; Henderson 2000; Thornton and Rehren 2009; Martinón-Torres and Rehren 2014). The glass fusion in the interior of a crucible and the presence of parting layer are the most striking evidence that a crucible was used in glass making and/or glass working. Studies of glass fusion and other residues in crucibles with other glass materials associated with pre-industrial production sites have helped to understand the raw materials used in early glass production and their sources. In the section that follows, I discuss the raw materials used in glass production among ancient societies and the basic chemical compositional groups known so far.

Components of Early Glass

Acquisition or the sourcing of raw material is the first, crucial step in glass making. A poor choice of raw materials will have direct impact on the entire production process (Henderson 2002:594), as well as the end product. Raw materials must be studied before the finished products can be understood.

Silica and alkali were the main raw materials of ancient glass production. Calcareous materials, iron oxide, manganese, and copper are further ingredients although, as further discussed below, they are often present in glass as colorants. Many studies of chemical compositions of ancient glass have revealed that these ingredients occurred as major, minor, or trace elements.. In this section, I first describe the major raw materials used in glass production. Second, I discuss other materials used for glass production and their effect on the overall quality (i.e. durability and stability) and appearance of glass. In terms of the appearance of ancient glass, I discuss the agents used as colorants, decolorizers, and opacifiers. Lastly, I discuss the chemical composition groups known for ancient glass around the world. It should be noted that there is variation across geographical regions in glass production methods. This variation, as will be discussed below, is often subject to the choice/source of raw materials, especially alkalis, and the preparation of the glass batch recipe.

Major Raw Materials

Silica

Silica is a major component of glass, which is mostly derived from quartz sand or rocks such as chert and quartzite. Since quartz-rich materials have been identified as a good source of pure silica (e.g. Shortland, 2005), it is not surprising that for several millennia ancient societies exploited both rocks and sand as sources of silica in glass making. Archaeological evidence in form of quartz dust, suggested to have resulted from crushing of quartz pebbles, from the LBA Egyptian site of Qantir Pi-Ramesse suggests that the people in New Kingdom Egypt explored quartz rocks as a source of silica for glass making (Rehren and Pusch 2007, 2008). Similarly, Henderson *et al.* (2004, 2005) have demonstrated that crushed quartz pebbles were used as siliceous mineral in production of glass during the Islamic period at al-Raqqa, Syria. On the other hand, evidence of the use of sand as source of silica for ancient glass has also emerged. The works of Freestone (2005, 2006) have revealed that sand was a major source of silica in the production of the first millennium A.D. Mediterranean and Medieval European glass.

Freestone (2006:205) suggests that sand was the preferred source of silica for glass making in antiquity. If the efforts required in crushing quartz rock are considered, one will be tempted to say that Freestone's claim is right. However, considering the evidence from LBA Egypt and the Islamic period, two factors are fundamental to the choice of the source of silica in antiquity. First, the availability of siliceous quartz materials; and second, the pureness of the quartz material to provide good silica needed for glassmaking. These two factors are important at the very initial stage of preparation of glass production. As a result, studies have shown that ancient societies exploited both materials either from their immediate surroundings or imported of pure raw material from other sources (e.g. Lucas 1948; Turner 1954, 1956; Saleh *et al.* 1972; Henderson 1985; Shortland and Tite 2000; Degryse and Schneider 2008; Brems *et al.* 2012). Either way, the availability and purity of materials drives selection.

The purity of siliceous material is an important issue to be considered in glass making, which to a large extent determines the quality, composition, durability, and color of the end product. The fewer impurities in the raw materials, the better the quality and clarity of the glass produced. Feldspars, titanite, and epidote are common impurities in some sands (Henderson 2000:27); depending on the source of the silica, other impurities may include iron, manganese, alumina, and lime. Some of these impurities can act as an alkali flux in the glass melt, although alkali is usually deliberately added by the glassmaker.

Alkali

Alkalis are essential raw materials used in glass production. Sodium oxide (soda) and potassium oxide (potash) were the most common alkalis exploited by ancient glassmakers as fluxes. Silica normally requires temperatures above 1700 °C to melt, and since ancient societies were unable to generate such heat, alkalis were introduced into the batch as fluxing materials to lower the melting temperature of silica. Soda and potash modify the silica network, allowing the melt to be more fluid, less viscous and to flow more easily than pure silica (Goffer 2007:115-117).

Sources of soda for ancient glass. Turner (1956:283) identifies four possible sources of soda as raw material for glass in antiquity: "large-scale deposits resulting from the evaporation and drying up of former landlocked seas and lakes; leaching out of salt from soils; local evaporation in pans or pits of sea or river water; and the ashes of vegetable matter." These sources involve two different retrieval strategies: harvesting from saline terrestrial or marine deposits, and burning plants to produce ash. The use of harvested mineral soda is reflected in the chemical composition of the glass by elevated levels of sodium oxide (NaO). Alkali derived from plant ash (potash – K_2CO_3) will have elevated levels of oxides present in the plants, such as magnesia (MgO) and potassium oxide (K_2O) (Sayre and Smith 1961; Freestone 2006).

Archaeological and historical sources have revealed that the mineral soda known as natron was harvested from Wadi Natrun, Egypt as early as 800 B.C. (Shortland *et al.* 2006). Although natron is suggested to have been in use for mummification in Egypt as far back as 2400 B.C. (David 2000), it was not known as a glass raw material until the 1st millennium B.C.

Archaeological evidence has shown widespread use of Egyptian natron in Hellenistic, Roman and Byzantine glasses produced in the eastern Mediterranean until the 9th century A.D. (Shortland *et al.* 2006). At least five major, natron-based glass production groups were operating in the Levant and Egypt between the 4th and 9th centuries A.D. (Freestone *et al.*. 2008). Shortland *et al.* (2006) have discussed possible reasons for the shift to plant ash from natron as an alkali source in Egypt between the 8th - 9th centuries A.D.

Natural natron was not the only mineral source of soda used in ancient glass production. Although still limited, studies of *reh* have demonstrated the mineral as a possible source of alkalis for ancient glass in India (Henderson 2013:53). *Reh* is an alkali-rich mineral, which has high level of soda but low content of calcium and potassium. Brill's analysis of *reh* samples from Shikohabad, Indian, has revealed that the mineral is rich in alumina with elevated magnesium oxide up to 1% (Brill 1999:481). Other analyses of Indian glass show similar results (e.g. Dussubieux and Gratuze 2003). Both *reh* and Indian glass are high in alumina, suggesting that *reh* is the source of the alkali (Henderson 2013:53), although the extent of its use, especially beyond India, is still unknown. However, early glass production centers exploiting *reh* are suggested to have been located in South Asia (Dussubieux *et al*. 2008).

Plant ash was the second major source of alkalis widely used in ancient glass production. Studies in the Middle East, and the Mediterranean have shown that plant ash was derived from both coastal and inland plants. Halophytic plants grown in the desert or coastal saline environment were exploited as source of alkalis in the ancient societies. Early works of Turner (1956) and Brill (1970, 1999), with recent efforts of Tite *el at* (2006), Barkoudah and Henderson (2006), Tanimoto (2007), Rehren (2008), Tanimoto and Rehren (2008), and Henderson (2013) among others, have not only demonstrated the use of varieties of species of halophytic plants in ancient societies, but also shown the compositional variations in plant ash glass and the factors that may account for the variations. Consequently, plant ash from the desert/saline riverbeds differs in composition from the ash of inland plants. The former have a relatively high soda content, while the latter are relatively rich in potash" Turner (1956:285) (see more discussion on plant ash in the composition section). The difference or variation in the composition of plant ash is a strong indicator of what source of alkalis had been used in ancient glass (Henderson 2013). However, plant ash was not only an important constituent of glass but also a vital multi-use substance (Turner 1956:285; Tite *et al.* 2006:1285).

In medieval and early modern Europe, alkalis were also derived from wood ash for glass making. The major difference between plant ash and wood ash is the sodium content. While the ash of halophytic plants is predominantly rich in sodium, other ordinary plants are rich in potassium. Experimental studies have shown that wood ash tends to have elevated potash, although some wood ash may have more calcium than potassium (e.g. Stern and Gerber 2004; Jackson and Smedley 2004; Jackson *et al.* 2005). However, there is large compositional variability in wood ash, which mostly results from factors such as the plant habitat, species, and plant part (Stern and Gerber 2004; Jackson and Smedley 2004). Jackson *et al.* (2005:791) have suggested that seasonally renewable plants, such as bracken, tend to present more compositional problems to the ancient glass maker, since their "elemental concentrations can change year by year depending upon soil, climate, ground cover, harvesting cycles and so on."

There is no doubt that the processing of ash from wood, as a source of alkali, would have been a tedious adventure. This process first involved gathering of the right wood rich in the required alkalis for glass. Then, the ancient glassmaker would have spent considerable amount of time in burning the wood to ash. Unfortunately, this cannot be measured archaeologically. However, the experimental work by Stern and Gerber (2004) has provided us with a sense of the degree of efforts that would have gone into making of ash from wood. They estimated that at least 500 kilograms of wood would be needed to produce 1 kg of raw glass (Stern and Gerber 2004:150).

Other Raw Materials

Calcareous materials

Calcium oxide (lime) is an important stabilizer in glass, improving its durability by impeding corrosion due to moisture. Calcium oxide can occur naturally in glass as part of the source of silica or source of the alkalis used. Studies have shown that shell in beach sand and the ashes of some plants were possible sources of the calcium oxide in ancient glass (e.g. Henderson 2000, 2004; Stern and Gerber 2004). However, calcareous materials can also be added intentionally to the glass batch. Various investigations have revealed possible sources of calcium oxide in raw materials in ancient glass production. These sources of calcium for ancient glass production include limestone, shells, and plant (Henderson 2000, 2013; Freestone 2006; Ige 2010; Basso *et al.* 2008).

Chemical analyses of ancient glass have helped to determine whether calcium oxide occurred as natural constituent in the source of silica or was added as a raw material. For example, if the source of calcium was natural in the silica source, the composition of calcium oxide in the glass is expected to be low, while an elevated level of calcium oxide may indicate deliberate addition. However, this is not always the case, as other factors could have been responsible for the level of calcium oxide in ancient glass and need to be considered before coming to a conclusion. For instance, the melting temperature affects the concentration of calcium oxide in glass, which in the long run determines its maximum content (Rehren 2008:1348).

Lead

Lead oxide is another important constituent of glass that was explored in antiquity. Although its use as a major raw material for glass is not common to all ancient glass, lead oxide has gained considerable attention in the studies of ancient glass in particular and vitreous materials in general (e.g. Charleston, 1960; Sayre and Smith, 1961; Henderson and Warren, 1982; Wedepohl *et al.,* 1995; Wedepohl and Baumann, 1997; Tite *et al.*, 1998; Tite *et al.* 2008; Bayley, 2009; Molina *et al.*, 2014). This attention given to lead is, in part, due to its multi-function in glass. Thus, lead “can be used as an opacifier, a flux, or a stabilizer” (Mecking 2013:640), as well as a former. For example, Biek and Bayley (1979:16) have suggested that like silica, lead could be a major component of glass with concentration up to 90%; therefore appeared as glass former. In addition, Turner (1956:175T) points out that lead oxide could be present in glass as both major and minor element with concentration as much as 30% up to 75% and at least 0.5% respectively. As a flux, and compared to wood ash and soda, Mecking (2013:641) suggests that the melting temperature of lead glass is much lower, and that "lead glass can be processed in a simple furnace or on an open fire."

Although it is unclear exactly when lead oxide was first used as raw material for ancient glass, ancient Mesopotamian texts dating to the 7th century B.C. (Oppenheim 1973), medieval writings of Heraclius (Davis-Weyer 1986), and the historic writings of Antonio Neri in the early 17th century AD (Lance and Ian 2002) all mention lead oxide as part of the raw materials in glass making and or working. These historical sources have been widely cited for understanding the processes, technologies, and raw materials used for ancient glass making (e.g. Charleston 1960; Sayre and Smith 1961; Biek and Bayley 1979:16; Henderson 1985:276, 2000:27; Mecking, 2013).

Archaeological evidence has revealed the use of lead oxide as major constituent of glass in Europe and China (e.g. Mecking 2013). In the Mediterranean and Europe, lead oxide had been identified as major component of glass since the Roman period. However its use was not widespread, for example, across Europe until between the 9th and 14th centuries. Tite *et al.* (2008), and Mecking (2013) have provided a summery of the evidence and spread of lead oxide as glass constituent from Western to Eastern Europe. Thus, Mecking (2013 648) refers to the 10th and 14th centuries as the "high point for lead glass," and suggests this to have been aided by the "increase in the extraction of silver, whereby lead occurred in larger quantity as waste product."

In spite of the numerous evidence of lead oxide as glass component, it is significant to note that, with the exception of medieval Europe and Han-period China, lead oxide was not a major raw material for glass. However, the presence of lead oxide in glass is of great significance, which has been proved to serve several functions from former and flux to colorant and opacifier. In fact, most of the occurrence of lead oxide in ancient glass is associated with coloration. Charleston (1960:2) opines, "Lead-glass was used essentially as a base for colored glasses". Lead glass has been suggested to epitomize brilliance and aesthetic of adornment in nearly every highly colored form (Biek and Bayley 1979:17). I discuss lead oxide with other agents of colorants, decolorants, and opacifiers below.

Several decades of archaeological research and improved analytic techniques for studying glass chemical composition have resulted in characterization of ancient glasses based on their compositions. These compositions reflect, as mentioned earlier, not only the major components of glass, but also the other secondary raw materials used in the production. The combination of these raw materials and their percentage of occurrence of each element and compound in the glass are then used to form compositional groups. The ingredients of glass have been grouped into three categories: major, minor, and trace. While the first two categories refer to formers, modifiers, and stabilizers, the last refers to either the other natural properties of the source of silica as well as alkalis, or ingredients added to glass batch as colorants and opacifiers. These compositional classes are discussed below. However, before I move on to the discussion on glass composition in ancient societies, I will first present a brief discussion on the agents of coloration and opacification of ancient glass.

Glass Colorants, Decolorizers, and Opacifiers

The physical appearance of glass in terms of the coloration is an important characteristic of glass, which set it apart from other ancient materials. As Henderson (2013:65) has suggested, the ability to mimic semi-precious stones such as lapi lazuli in colored glass may be the reason for its invention and spread. Compositional analysis of ancient glass reveal not only the raw material used in glassmaking but also the colorant agents and other additives such as opacifiers. The colorants and opacifiers mostly occur as minor or trace elements in glass compositions, which together usually make up less than 5% of the total mass of glass (Goffer 2007:120). I do not intend to discuss the chemistry of colorants and opacifiers in depth here; rather I will include only the principal agents of coloration, decoloration, and opacification as well as the factors that affect color types and shades.

Colorants

The use of colorants in ancient glass is widely debated in the literature on early glass production. Transition metal oxides such as manganese, cobalt, copper, and iron were the main agents for coloration of ancient glass. These metal ion responsible for ancient glass coloration were derived from “an unrefined mineral ore containing a proportion of the colorant element but associated with others; a mineral ore which, as in the case of a metal ore, after preparation and purification, may have been crushed, washed, and roasted before use; a colorant frit, containing the colorant oxide in a diluted form; and either glass cullet or cakes of highly-colored ready-prepared glass” (Henderson, 1985:278). For example, Heck and Hoffmann (2002) have demonstrated that certain oxidized metals and alloys such as lead, copper, bronze, brass, and their mixtures, and iron slag were used as colorants in the 5^{th}–7^{th} century A.D. Merovingian period in Europe for producing glass in green, orange, and brown colors. In Bronze Age Italy, copper oxide was the most common colorant for glass in red, light blue, and green colors (Santopadre and Verita 2000:38). Also cobalt was a main source of dark blue coloration in LBA Egypt, the Islamic period, and Medieval Europe (e.g. Sayre 1964; Kaczmaczyck 1987; Rehren 2001; Henderson 2003; Pusch and Rehren 2007).

The final glass color and the elemental concentration are determined by various factors including the kind of mineral or coloring agents added, how the colorants were mixed, and the condition of the furnace during production. Henderson (2000:29-30, 2013:65-8) has detailed the factors that determine glass color. Take for instance the effect of the concentration of colorants oxides. Iron oxide is a common mostly naturally occurring impurity in glass raw material, and a colorant. Small amounts of iron oxide in the glass batch result in glass with a green tint or as termed by Henderson (1985:278) “weakly colored glass”. Pusch and Rehren (2007:185) explain that the presence of iron and manganese oxide in the LBA cobalt blue glass may have also occurred unintentionally. Furthermore, Biek and Bayley (1979) describe how the color of glass with moderate iron oxide could change under different furnace conditions. They state that iron oxide in fully reduced state appears blue, but turns yellow when fully oxidized (Biek and Bayley, 1979:14). Table 3.1 summarizes the colorant agents and the color they produce in difference furnace environments.

Decolorizers

Although most literature seems to discuss early colored glass, there is evidence that clear or colorless glass was also produced. Heraclius' account mentioned clear glass produced in Roman world (Davis-Weyer 1986). Archaeological samples of clear glass have been recovered (e.g. Jackson 2005; Baxter *et al.* 2005).

Glass color	Colorants	Furnace condition
Black	Manganese Iron	Reducing Reducing
Red	Copper Gold	Reducing Reducing
Pink	Manganese	Oxidizing
Yellow	Uranium Silver	Oxidizing Reducing
Green	Copper Iron Chromium	Oxidizing Reducing Oxidizing
Blue	Copper Cobalt	Oxidizing Reducing
Violet	Manganese	Reducing

Table 3.1: Glass Coloring Agents and their reactions under different furnace condition (Modified after Goffer 2007: 121)

Colorless or clear glass can be produced in two ways. The glassmaker could deliberately add decolorizer oxides such as manganese and antimony oxides, both of which were used in Roman clear glass (Jackson 2005; Foster and Jackson 2010). Although manganese amounts as small as 0.5% are enough to make clear a glass batch with an iron content of about 0.5%, antimony is said to be a stronger decoloring agent. Occasionally the use of manganese oxide can "produce a very faint purple tinge and antimony trioxide a faint yellow tinge" (Henderson 2000:38). Sayre and Smith (1967) note the presence of colorless glass with antimony as decolorizer in the Middle East starting from 700 B.C. By the late first century B.C. the Middle East glassmakers introduced manganese oxide as decolorizer. The production of colorless glass using antinomy or manganese oxides as decolorizer increased tremendously in the Roman period (Jackson 2005; Foster and Jackson 2010).

The second way of producing clear glass relies on the skill of the glassmakers in raw material selection, and in manipulation of melting conditions and additives. Pure raw materials with very minimal or no impurities can produce clear or colorless glass (Shortland 2002:517). Furthermore, the high or low occurrence of decolorizer oxides in glass composition and the apparent colorless of glass have technological significance in ancient glass production such as careful selection of raw materials, appropriate measure of decolorizer, and sound knowledge of furnace control (Foster and Jackson 2010:3068). Jackson (2005:763) argues, "colorless glasses are a good medium through which to show the skill of the … glassmaker and illustrate the influence of the choice of raw materials."

Opacifiers

In ancient glass, antimony and tin compounds were the major agents of opacification. Antimony was added to the glass batch in the mineral stibnite, which reacted with other components of the melt to form metal antimonates (Goffer 2007:123). These antimonates result in specific color and opacity of the glass. Pure calcium antimonate will produce white opaque color, while lead antimonate will result in yellow opaque glass (Turner and Rooksby 1959).

Like antimonates, the color of glass with tin oxide as opacifier varies depending on the compound of the tin added to or present in the glass. When present as pure tin oxide the glass appears white and as yellow when present as lead-tin oxide (Henderson 1985:285; Tite *et al* 2008).

Compositional studies of ancient glass and experimental works have shown the antiquity of opacified glass in both yellow and white colors. Tite *et al*. (2008) present an excellent summary of the antiquity of opacified glass around the world. I will briefly mention places with evidence of the use of both antimony and tin-based opacifier in antiquity and their regional spread. Although this discussion is largely drawn from Tite *et al.* (2008) summary, Turner and Rooksby (1959), Rooksby (1964), Henderson and Warren (1983), Mason and Tite (1997), Tite *et al.* 1998, Freestone and Stapleton (1998), Bayley (1999, 2000), Heck and Huffman (2000), and Heck *et al.* (2003) have also provided fascinating archaeological, compositional, and experimental research on the production and use of opacifiers in ancient glass.

Antimony-based opacifiers were used earlier than tin-based ones. The first evidence of the use of antimony-based opacifier came from the Near East and Egypt at about 1500 B.C., and continued into the Roman period. Shortland (2002) discusses the technology and provenience of calcium and lead antimonates in early Egypt, and is of the opinion that Egyptian antimonates would have originated from the Caucasian antimony mines going back to the 17th century B.C. (Shortland 2002:527-8). Between the 2nd and 1st century B.C. both antimony and tin-based opacifier were used in parts of Europe. By the 1st century A.D. there was a shift from antimony-based opacifier to tin-based in the Roman world. In the Eastern Mediterranean, tin-based opacifiers replaced antimony at about the 4th century A.D. Consequently, the use of tin-based opacifier spread across Europe in the 5th century A.D. and lead tin oxide was extensively used in yellow glass between the 5th and 9th centuries A.D. in many European countries. In the Islamic world, the use of tin-based opacifier in glass production began in the 9th century A.D. It was first used in the production of white opaque glass, and by the 12th century it was used in both white and yellow opaque Islamic glass.

Early Glass Compositional Groups

The advancement of studies of vitreous materials in ancient societies has helped to address questions of origin, raw materials, technology and production processes, and compositions. This development is accomplished through the interpretation of chemical compositions of glass, and comparative studies with experimental works. For over five decades various analytical techniques have been used on ancient glass samples, which include emission spectrographic, x-ray diffraction, scanning electron microscopy, electron micro-probe analysis, neutron activation analysis, auger emission spectroscopy, and x-ray fluorescence analysis, among others. More recently, laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) has gained attention and helped a great deal in the compositional analysis of ancient glass (Robertshaw et al. 2003, 2006; Dussubieux and Gratuze 2003; Dussubieux et al. 2008, 2010), especially in the analysis of trace elements. In addition, isotopic analysis has become a veritable tool for analyzing glass, which has also contributed to our knowledge of the nature and origin of raw materials for ancient glass (Freestone 2005, 2006).

The analysis usually presents the concentration of the chemical composition of glass. The following components: silica, soda, potash, lime, magnesia, manganese, iron and other oxides are considered as major or minor elements in glass. They are "expressed as a percentage of the total mass of glass" (Goffer 2007:128). The combinations of percentages of various elements are used to form a compositional category, based on the concentration of major, minor, and trace elements. However, as already mentioned above, the percentage of each element or oxide in a compositional category or subcategory is never fixed, but always varies both within a given category, and from one ancient society to another and between different production centers within the same society. These variations depend on several factors such as the intentional addition of fluxing materials or the natural occurrence of minor and trace elements in the raw materials. In this section, I present a discussion of the major ancient glass compositional categories from around the world such as plant ash and mineral soda glasses.

Soda-lime-silica glass

Most ancient glasses have soda, lime, and silica as their principle components. As stated by Robertshaw *et al.* (2010:1902) "the kind of soda used to make this glass is sometimes diagnostic of broad region and/or chronological period. Research has shown that this type of glass has been used for about 3500 years in Mesopotamia, Egypt, Greece, Rome, India, and the Byzantine and Islamic world as well as throughout the Mediterranean and parts of Europe from the mid-2nd millennium B.C. through to the late 2nd millennium A.D. (e.g. Brill 1988; Henderson 2002; Freestone et al. 2002; Freestone 2006; Degryse and Schneider 2008; Schibille 2011). The commonality of soda-lime-silica glass in ancient times may be attributed to its accommodating characteristics, namely that it was "easy to melt and shape and reasonably strong" (Kanungo 2004:5).

There are two major sources of alkali for soda-lime-silica glass: plant ash and mineral natron. The regional wide sourcing and processing of plant ash and mineral natron has been mentioned earlier. However, it should be added that magnesium oxide is a common differentiating element between these sources of alkali for ancient glass. While plant-ash based soda glass has more than 2.5% of MgO, mineral-natron based soda glass has considerably less, typically less than 1.5 wt% (Robertshaw *et al.* 2010), although the concentration may vary considerably depending on some technical and reaction factors (Henderson 2000:56-7).

The earliest occurrence of soda-lime-silica glass is in Mesopotamia and Egypt, in the 2nd millennium B.C. The use of soda-rich plant ashes provided a slightly higher amount of magnesia and potash than the later mineral-natron based glass from the Roman period. Plant-ash based soda-lime silica glass re-emerges in the early Islamic period and remained in use in the Middle East until the early modern period.

Plant-ash glass

Since plant-ash glass derives many minor and trace elements from alkali as well as silica (Freestone 2006:212), the composition varies, which makes it difficult to define a typical plant-ash glass. Despite the complex nature of plant-ash glass, several decades of analytical work on archaeological glass have provided us with average standard chemical composition expected in plant-ash soda-lime glass. The base elemental average for plant-ash is 65% SiO_2, 18% Na_2O, 8% CaO, 4% MgO, 2% K_2O (Brill 1999; Rehren 2000; Pusch and Rehren 2007; Henderson 2013). It should be noted, however, that this basic element average is characteristic only for the LBA Egypt and the Islamic world; elsewhere, there are regional variations, as for example in Bronze Age southern Europe (Henderson *et al.* 2004).

Archaeological evidence has revealed that plant-ash glasses were produced in LBA Egypt's primary glass workshop (Smirniou and Rehren 2011; Pusch and Rehren 2007). Plant ash glass was also in circulation throughout the Sassanian Empire starting in 3rd through the 7th centuries A.D. Between the 7th and 9th centuries A.D., Islamic glassmakers west of the Euphrates shifted to plant ash from mineral soda (natron) as a flux. (e.g. Shortland 2006; Freestone 2006). The reasons for this change alkali range from supply and demand and environmental factors to political upheaval in the Mediterranean, which could have prevented the circulation of natron-based glass and/or raw materials Shortland et al. (2006:527). Henderson (2002) has also describes experimentation with plant-ash alkali in the late first millennium Islamic world. He refers to the replacement of natron with plant ash as a "revolution in glass technology", which brought about technical changes to the production process. The changes include easier sourcing of alkalis as halophytic plants were common across the Middle East on the desert margins, and lower glass melting temperatures because soda and higher potassium level were introduced to the batch from the plant-ash, which invariably lowered the amount of fuel required for melting (Henderson 2002:598).

The period between the 8th and 9th centuries witnessed extensive plant-ash glass production throughout the Middle East. The site of al-Raqqa in Syria was an active plant-ash glass production center during this time. The evidence at al-Raqqa has not only revealed the compositional complexity of plant-ash glass, but also shown that there was a significant increase in production of glass, which enhanced trade in plant-ash glass within the region and beyond (Henderson 2002, Henderson *et al.* 2004).

The intensity of the production of plant ash glass in the Islamic world and the entire Middle East allowed trade in the produce further afield, especially Europe during the medieval period (Jacoby 1993). For example, Venetian glassmakers were importing plant ash glass from Syria. The imported glasses mostly appear in unfinished form, which was then fused with local quartz to make new glass in secondary glass making workshops (Freestone *et al.* 2002; Freestone, 2005, 2006). Although some glass chunks or finished objects would have been exported from the Middle East to Europe, this was probably restricted to a few isolated instances (Rehren 2014, Pers. Comm.).

Plant ash glass also reached Africa along trade routes: in West Africa, plant ash glass beads have been identified at Kissi in Burkina Faso; Jenne-jeno, Gao Ancien, Gao Saney, and Es-souk in Mali; and Igbo-Ukwu in southeast Nigeria (Brill 1999; Cisse 2011; Cisse *et al.* 2013; Lankton n.d.). Plant ash glasses have also occurred in some archaeological sites in southern Africa as well as Pemba in Tanzania and Shanga in Kenya from mid 1st through late 2nd millennium A.D. (Wood 2009; Wood and Roberthshaw 2009; Robertshaw et al. 2010).

Mineral-soda glass

Mineral-soda glass is a description often used to refer to natron glass made with evaporitic minerals as the source of soda. Wadi Natrun in Egypt and other locations have been identified as a major source of natron for ancient glass (e.g. Shortland 2004, Shortland et al. 2005). Natron glasses are distinctive because of their low magnesium and potassium oxides levels, which are usually less than 1.5 % and 1% respectively (Brill

2001; Henderson et al. 2004; Brems *et al.* 2012). Reported basic elemental concentrations of natron glass average 65% SiO_2, 15% Na_2O, 10% CaO, 1% MgO, 1%K_2O, with variation present within the compositional group.

Natron glass characterized the Hellenistic, Roman and Byzantine periods between the 1st and 3rd centuries A.D. Natron glass also dominated the Mediterranean and the surrounding regions between the first millennium B.C. and 9th century A.D. (Freestone 2005:2). Studies of natron glass from the 1st millennium A.D. have yielded five different sub-groups: Levantine I, Levantine II, Egypt I, Egypt II, and High Iron Manganese Titanium (HIMT). All have elevated levels of Na_2O and low FeO_2 concentrations. However, HIMT contains elevated levels of iron, manganese, and titanium from which it derives its name. In addition to the high iron manganese and titanium in this category of glass, they also have elevated Na_2O and K_2O and MgO below 1.5%, which indicate soda-lime-glass with natron as the source of alkali (Freestone 2005:10; Freestone *et al.* 2005:153). This distinctive HIMT natron glass first occurred between the 4th–6th century AD in Egypt and the Mediterranean and spread across many regions in Europe.

Mineral-Soda-alumina glass. This is mineral-soda glass characterized by a high concentration of alumina, which varies from 5 to 15%. Reported compositional characteristics are around 10% Al_2O, 3% CaO, <1% MgO, and >1.5% and K_2O (Dussubieux *et al.* 2010). Mineral-soda-alumina glass is dated to the first millennium A.D. in South Asia, where it gained considerable dominance (Brill 1987). Mineral-soda-alumina glass was also known in Late Byzantine Pergamon, modern-day western Turkey in the 12th–14th century A.D. Schibille (2011) refers to this group as Asia Minor.

Recent chemical analysis of glass from India, Sri Lanka, Bangladesh, Thailand, Malaysia, Indonesia, Cambodia, Vietnam, Turkey, and Kenya by Dr. Dussubieux and her colleagues have identified five sub-groups of soda-alumina glasses called m-Na-Al 1 through m-Na-5 (Dussubieux *et at* 2008, 2010:1650-2). This study is significant for two reasons: 1) it draws samples from sites dated from the 5th B.C. through the 19th Century A.D. and 2) it considers not only major and minor elements (calcium and magnesia) of the composition but also uses trace elements such as uranium, zirconium, barium, strontium, and cesium to identify sub-categories. Wood *et al.* (2011) and Robertshaw *et al.'s* (2010:1903-8) analysis of glass beads from Southern Africa belonging to K2, K2

GR, Indo-Pacific, and Khami series revealed that they have m-Na-Al 2 chemical characteristics, although there are variations especially among the Khami series. This group is also known in East Africa, but is rare in West Africa.

Wood ash glass

Wood ash glass uses potash derived from the wood ash as alkali in the glass batch.. Sometime wood ash is very rich in calcite (Ulery *et al.* 1993), which could make the ratio of their calcium oxide to potassium oxide increases (Wedepohl and Simon 2010). The concentration of potash could be as high as 15%, with sodium content about 2% or less. Archaeological evidence has revealed that wood ash glass was produced since the late 1st millennium AD in Europe, and became the predominant glass type by the medieval period throughout Europe (e.g. Wedepohl 1997; Smedley and Jackson 2002; Wedepohl and Simon 2010).

Lead glass

Ancient glass with high lead oxide content and low alkali and lime is classified as lead glass. In this case, lead oxide and silica usually form the base components of the glass. Based on the analysis of glass objects from central Europe, Mecking (2013:643) has suggested the following compositional range: SiO_2 content ranges from 19% to 50%, PbO lies between 43% and 78%, K_2O reaches maximum of 16%, while all other components are less than 3%.

Although there is evidence of lead glass in Mesopotamia in the 4th and 5th century B.C., in China and India, lead did not become a major component in glass production until the medieval period when the tradition proliferated in Han China continuing up to the 13th century A.D. (Fuxi 2009) Similarly, lead-silica based glasses dominated in 19th century Thailand (Won-in *et al.* 2001).

Lead glass has also been identified in some archaeological sites in North and West Africa dated to between the 1st millennium A.D. and the early second millennium A.D.: Al-Basra, Gao, Kissi, and Essouk (Robertshaw 2007; Robertshaw *et al.* 2009; Cisse 2011). Of the six high lead glass beads identified from a first millennium context in Gao, four samples have elevated lead content between 15 and 25%, while two samples have very high lead level above 40% (Cisse 2011). Although these percentages are low when compared to Mecking's average, they are high enough to suggest a new sub-group of lead glass. The 17th–18th century site of Garumele, Niger has also yielded some lead-silica glass (Robertshaw *et al.* 2014). The pioneering neutron activation analysis of African glass beads by Davison *et al.* 1971 identified lead glass in Dahomey and Old Oyo.

Mixed alkali glass

Henderson (1988:77) defines mixed alkali glass containing "significant levels of both soda and potash." Tite *et al.* (2013:1284) describe mixed alkali as "plant ash characterized by potash content … a little higher than those of soda, and by low lime and magnesia content." In other words, the level of soda in relation to potash is an important criterion in determining glass fluxed with mixed alkalis. Glass and other vitreous materials fluxed with mixed alkali plant ashes were known in parts of the Mediterranean during the 2nd millennium B.C. Glass fluxed with mixed alkali was known in Europe by 11st century B.C. (Brill 1992; Santopadre and Verita 2000; Arletti *et al.* 2010a &b; Henderson *et al.* 2014). Experimental work on the ashes of *Salsola kali* from Egypt and Europe revealed low soda to potash ratios (Tite e*t al.* 2006: 1289-1290). This ratio matches the mixed alkali glass from Western Europe, which suggests that the ash may have been derived from *S.kali* (Tite e*t al.* 2006: 1291). Results of the isotopic analysis of glass samples from Frattesina, northern Italy has shown that the earliest glass produced in Europe was mixed alkali glass (Henderson *et al* 2014: 7-8).

Glass in Sub-Saharan Africa

The presence of plant ash, mineral ash, glass and lead glass at various sites in sub-Saharan Africa is the result of trade networks, both trans-Saharan and Indian Ocean, that extended to source areas in the Near East (Palestine, Syria), Middle East and the Mediterranean (Dussubieux 2009; Robertshaw 2010; Wood 2011). As a result most glass artifacts in ancient sub-Saharan African have been suggested to originate from Egypt, Mediterranean, the Islamic world, and southeast Asia (e.g Insoll and Shaw 1997; Sutton 2001; Robertshaw *et al.* 2010; Wood 2011), and much later from Europe. However, chemical analyses of glass from Ile-Ife, southern Nigeria have identified a distinct compositional group of very high alumina glass that was likely produced locally in southern Nigeria (Lankton *et al.* 2006; Freestone 2006). The proposition that primary glass production took place in Africa is quite recent. Archaeological evidence of primary production is lacking. Some scholars have nevertheless viewed the glass debris that abounds in Ile Ife as liked to glass-making. Cheik Anta Diop suggested that workers "utilized as raw material sand, sherds and glasses, which they blow or mold into various objects (beads, bracelets, e.t.c.)" (Diop 1987:205). He suggested that "besides beads of Egyptian, Phoenician, or Venetian origin, there are those of properly local creation" (Diop 1987, 205). Similarly, Robin Horton (1992:132) proposed that at Ife "…we should have to give strong consideration to the possibility of indigenous manufacture of the raw glass." These arguments were primarily based on the occurrence of crucibles, manufacturing debris, and both finished and unfinished glass beads from Ile-Ife and its surroundings (Eluyemi 1987, Adeduntan 1985), Early compositional analysis of Ile-Ife glass beads by Davidson (1972) had little in the way of a comparative database from different source areas; she concluded that glass was imported and re-melted at Ile-Ife, a conclusion that Willett (1977, 2004) also advanced.

However, the work of James Lankton, Akin Ige and Thilo Rehren (2006) on glass beads, crucible fragments, and cullet from Ile-Ife, Ian Freestone's (2006) commentary on this work, and the more recent work of Ige *et al*. (under review) on the geo-chemical analysis of glass materials from Oshogbo – southwest Nigeria, have opened up a robust discussion on the possibility of primary glass production in southern Nigeria between the 10th and 18th century A.D. In chapters 7 and 8, I compare results of this work with my data from Igbo Olokun. In the final section of this chapter, I will discuss the main arguments of Lankton *et al.'s* and Freestone's arguments concerning probable primary glass production in sub-Saharan Africa with emphasis on southern Nigeria.

Lankton *et al.'s* work offers the first use of geochemical evidence to argue for a local source of raw material for some Ile-Ife glass. Although the chemical analyses by Davidson (1972) and Willett (1977) identified the presence of a particular kind of glass characterized by high lime and alumina levels (High Lime High Alumina glass), Lankton *et al.* (2006:136) were the first to suggest that HLHA glass is " a glassmaking tradition unique to West Africa", contrary to the prevailing view that the bead making industry in

Ife used imported glass (Willett 2004, comment on T839, T610, T611). It also raises other important issues relating to raw materials used, and the technique of production.

As mentioned above, availability of raw materials is vital to primary glass production. Lankton *et al.* (2006) argue that the geologic composition of Ife and its surrounding would have provided ample opportunity for the inhabitants of early Ife to engage in primary glass production. According to the authors, the mafic and ultramafic rocks, the lateritic profile containing cobalt, copper, and vanadium, and the metamorphosed sediments of sillimanite-rich quartzites and mica schist, are abundant in or near Ile-Ife, and could have been exploited locally for siliceous material and colorants in glass production (Lankton *et al.* 2006:134). In addition, they assert that the kaolinitic clay deposit near Ile-Ife would have served as the source of the high-alumina in Ile-Ife crucibles and the glass. The authors also suggest that wood ash could have been prepared from the rich forest resource in and near Ife for use as an alkali (Lankton *et al.* 2006:134-5).

Another important issue raised in Lankton *et al.'s* article relates to the technique of primary glass production in Ife. Studies on ancient glass production have revealed two models of primary glass production: partial batch melting and complete batch melting (e.g. Rehren 2000). In these two models condition and control of the furnace temperature are strong factors. These factors usually impact both the end product (quality and quantity of glass) and the apparatus used in the production (furnace chamber or crucible). In the partial batch melting model, quality glass is produced and lots of waste from previous melts is reintroduced into the next batch, leaving very little or no residue (Lankton *et al.* 2006:130). There is evidence that may support both models of glass production being used in ancient Ife. However, this hypothesis still remain up for debate as Lankton *et al.* has concluded that "further study of the crucibles and their contained glass … will be helpful in choosing between the two glassmaking models" (2006:133).

Lankton *et al.* (2006) consider two theories on the possible development of glass technology in Ife. The first is the notion that glass industry was an organized institution that requires a lengthy apprenticeship. Upon graduation the apprentices travelled abroad to establish a new workshop. This theory rests on the assumption that the technology used in both the mother workshop and the daughter workshops are identical, irrespective of where they are located. The second theory stipulates that certain known products are reinvented.   In this instance, new technology is developed by imitation and emulation through trial and error. Although Lankton *et al.* recognize that it is difficult to find evidence for the second theory in the archaeological record; the authors suggest it is more likely that Ife glass technology was developed by reinvention of familiar technology (2006:134). This idea is further pursued in this dissertation.

Lankton *et al.'s* (2006) work has set the study of glass production in sub-Saharan Africa on a new path. Freestone's commentary provides additional context on the possibility of a local source for Ile-Ife glass. Considering the high metaluminos content of Ile-Ife glass, Freestone (2006:140) suggests the possibility of the use of alkali feldspar minerals in form of "immature granitic sand, or granitic/syenitic rock or pegmatite" with combination of shell, as pure source of calcium. Freestone's hypothesis that the high lime content in Ile-Ife glass was derived from addition of shell into the glass recipe has received support from experimental work by Ige (2010) supports. Freestone (2006:140) observed that if lime was added to HLHA glass in the form of a rock such a limestone or even as shell, "...we might have here a truly African technology… , something without precedent in early glass making as we currently understand it."

By and large the work of Lankton *et al.* and Freestone has contributed tremendously to our understanding of glass production in early Ile-Ife. There is now some evidence of possible primary glass production using local raw materials, in contrast to the conventional narrative that this area relied on imported glass. The study has also established pathways for discussing production techniques of and what could have stimulated the development of the technology in ancient Ile-Ife. It is therefore upon the foundation of Lankton *et al.'s* work and Freestone's that this dissertation builds, in its evaluation of the evidence for possible glass-making as well as bead production at Igbo Olokun.

Summary

Research on early glass production has expanded tremendously over the past several decades. Archaeological evidence, historical sources, and experimental works have greatly advanced our knowledge of the production processes, the use of various raw materials and their origin, and the compositional signatures of ancient glass as well as other vitreous materials. The antiquity of primary glass production and secondary glass working in LBA Egypt, Mediterranean, and the Roman and Islamic periods has been demonstrated over and over again. Also the roles of these known ancient glassmaking and glass-working centers in the spread of glass objects and the expansion of the know-how in the production in other parts of the world has been debated. However, there is evidence in the chemical compositional of ancient glass that other regions at different points in time produced glass locally using different recipes. The occurrence of certain archaeological materials in addition to data on density of materials and availability of raw material for glass, as well as the origin of raw material are major determinants for deciphering both primary and secondary workshops.

In sub-Saharan African there are very few studies of primary glass production sites. This is partially inspired by the lack of archaeological evidence of primary production sites on the sub-continent. On the other hand, investigations on glass in Africa – south of the Sahara – have largely focused on exotic glass objects, which are often treated as traded items. As a result attention is on the origin rather than the technology, and process of production. Hopefully, this will change in the face of new data on glass making and glass working in Sub-Saharan Africa surfaces. This dissertation seeks to fill the gap in our understanding of ancient glass production in sub-Saharan African by using different analytical techniques to examine the archaeological data from our excavations in Igbo-Olokun, Ile-Ife – Nigeria.

Chapter Four

ARCHAEOLOGICAL EXCAVATIONS AT ILE-IFE - 2010-2012

Introduction

The excavations[1] described here were carried out at the well-known site of Igbo-Olokun and the newly-discovered site of Igbo-Rudi (see Fig. 2.1). Preliminary test excavations were carried out at both sites in November and December of 2010, and the main excavations at Igbo-Olokun took place from late November 2011 through February 2012. This chapter first discusses the methods used during the excavations, including the types of instruments used for excavation, and the process of recovery, recording, and storing artifacts. It also describes the size of each excavation unit, their location within the sites and relative position as well as material composition and stratigraphic information. Finally, this chapter discusses the site chronology based on the data generated from the excavations as well as other data previously collected in Ile-Ife.

Igbo Olokun excavations

Igbo Olokun (Olokun Grove) has been recognized as a site of major archaeological significance since Frobenius dug up a terracotta head and "glazed"

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[1] The excavation crew included: Dr. Tunbosun of the Department of Archaeology and Anthropology, University of Ibadan; Dr. Ogunfolakan of Natural History Museum (NHM), Obafemi Awolowo University Ile-Ife; Mr. Awowoyin of Ile-Ife Museum; Mr. Olayiwola, Agbelusi, Olagoke, Bamisile, and Omogbai all archaeology students at the University of Ibadan at the time of the excavation; and Mr. Solomon, a community member. Dr. Ajala, Mr. Adekola, and Miss Yetunde Hassan also visited for one week and participated in the excavations. Miss Enuka, a Nation Youth Service Corp (NYSC) member at the NHM assisted during the last few weeks of the excavations. Mr. Olateju of NCMM Osogbo, Dr. Kasim, and Mr. Oladapo assisted during the 2010 test excavations.

ceramics now known to be glass-encrusted crucibles. The famous Olokun copper alloy head that Frobenius purchased and tried unsuccessfully to take to Germany also reportedly came from Olokun Grove. In 1960, Willett reported widespread disturbance to the subsurface deposits due to local pit digging to excavate and ritually rebury antiquities, extensive mining by the local population for old glass, and probes by archaeologists to locate undisturbed underground chambers. Seventy deep "well-shaft" probes were sunk by Fagg and Murray at unmapped locations over Igbo Olokun in 1953 in the hopes of finding an intact example of the 3-4m deep bell-shaped chambers first encountered by Frobenius (Willett 1960:241-2). This effort was unsuccessful, leaving untested Fagg's hypothesis (cited in Eyo 1970:45) that these were burials. In more recent decades, much of the former extent of the sacred grove has been reduced by expansion of private ownership and residential construction, another major source of subsurface disturbance. For this reason, all but one of the Igbo Olokun excavation units were placed within the fenced reserve maintained by the NCMM (Fig. 4.1).

The vegetation in this reserve includes banana plants, trees, and non-woody plants (Figure 4.2), all of which contribute to disturbing the soil to various depths. The banana plants create characteristic pockets of organically enriched soil to a depth of 40 cm. (Figure 4.3). As a consequence of the many disturbances to Olokun Grove subsurface deposits, Davison (1972:47) concluded that "this is no site at which to investigate the Ife glass industry". Our excavations would test that conclusion.

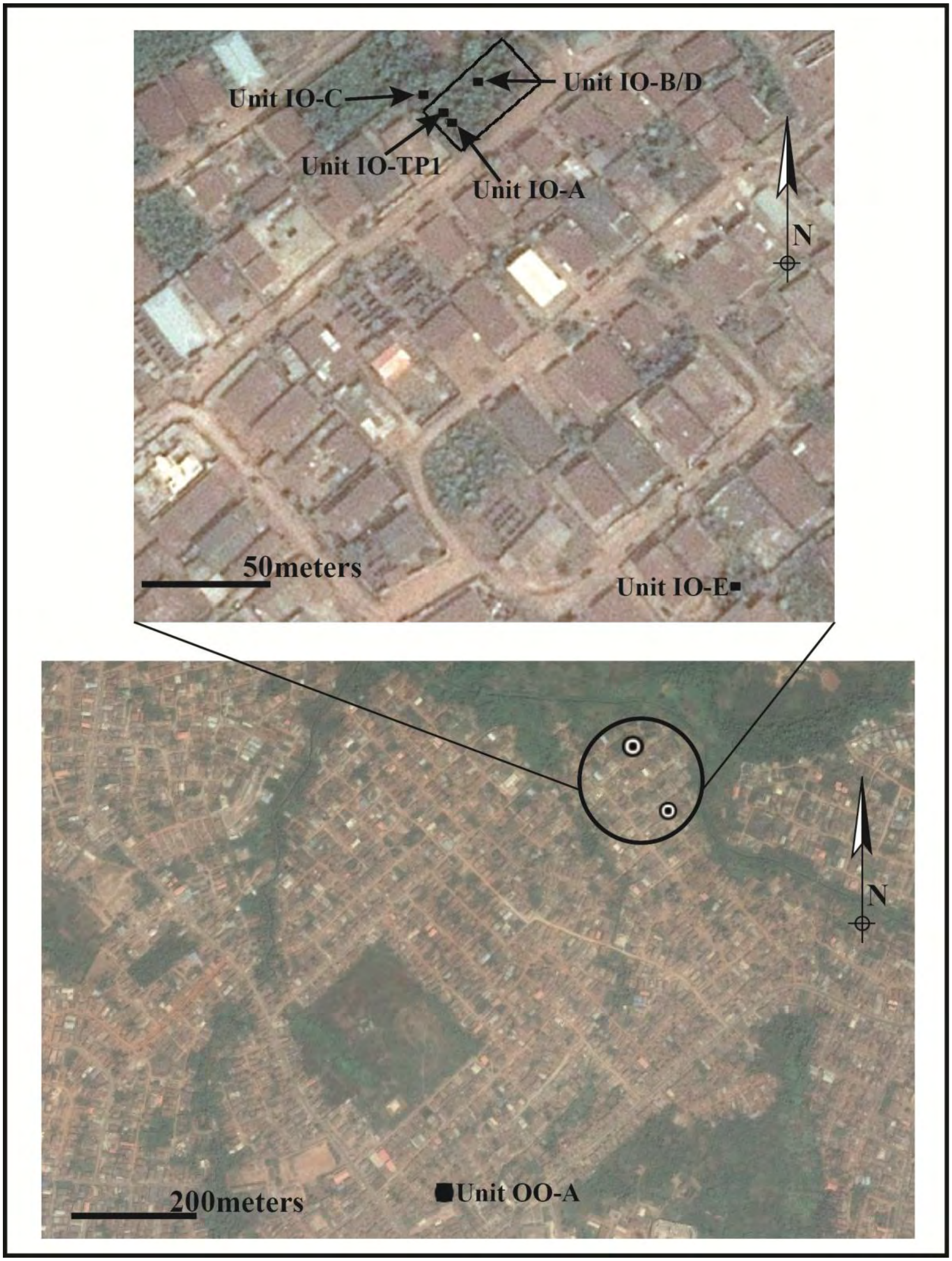


Figure 4.1: Site map showing the location of units IO-A through IO-E and IO-TP1. (Images adapted from Google Earth)

Figure 4.2. Vegetation in Olokun Grove today includes banana plants, trees, and non-woody plants.

Figure 4.3. Section showing pockets of darker organic soil created by banana plant root penetration.

The challenges of detecting disturbed contexts during excavation and maintaining stratigraphic integrity became clear in the first test pit dug in 2010. The thin surface layer of soft, organically rich soil was fairly easy to identify. The underlying reddish-brown horizon, which was present in all later excavation units, was difficult to interpret. It was variably soft or compact, with varying concentrations of gravel and flecks of laterite clay likely derived from the sterile, basal orange lateritic clay deposits. Pit intrusions were difficult to detect. For example, a pit feature became apparent at c. 55 cm depth in Test Pit 1 (Figure 4.4). Examination of the adjacent section revealed no obvious color or content changes above it that would indicate that the pit originated higher up (Figure 4.5), with the exception of looser texture along the west wall. After drying out, however, the extension of the pit almost to the surface became evident as the excavation continued through 80 cm of sterile lateritic clay. (Figure 4.6) Color changes occurred as freshly excavated areas dried. This made detailed recording of observations of freshly excavated areas imperative. The use of a spritzer bottle to moisten profiles would be potentially useful, but was not employed in these excavations. There is potential here for teasing out the various contexts, given sufficient attention to minor nuances of color, texture and content in the deposits, but it is also easy to see why Willett (1960:244) claimed that there was no normal stratigraphy to be found.

Figure 4.4. Dark pit fill is visible in the northeast corner of IO-TP1.

Figure 4.5. The height of pit fill above the level of the lateritic clay into which it was dug is not evident in the adjacent section.

Figure 4.6. IO-TP1 at bottom of excavation. The deep pit in the northeast corner is clearly visible. Arrow points north.

Excavation Methods

The excavations were carried out with trowels and mattocks, the latter used to break through hard deposits. The goal was to excavate by natural layers, but this proved challenging. The opening and closing of each level were photographed and detailed descriptions were kept in a field diary, including the nature and depth of the deposit, and the types and quantities of materials. All this information was recorded on Level Record Forms (LRF), one for each level. A new LRF was started each day, even if the level was the same. Because of the reasons discussed above, features were difficult to identify. Thus, features were, mostly, spotted in the profiles or on the floor plan after cleaning up. In the case of the latter, they were dug separately with the materials either merged with the previous level of the same deposit or assigned a new level number. The features were thereafter described in the field note and photographed. All artifacts from each level were bagged and labeled. Glass beads and glass debris were bagged together, and faunal remains were also bagged separately. All other categories of artifacts (pottery, crucibles, and stones) were bagged together at the site, and then separated later after they were washed and dried.

Deposits were screened through 2.5 mm mesh in 2010, but the presence of very tiny beads that passed through the mesh prompted a switch to 1.2 mm mosquito netting in 2011-12. This method, although time consuming, allowed us to collect more of the glass beads from the excavations in 2011 and 2012 compared to the 2010 test excavations. The beads were counted and weighed at the site; other artifacts, with the exception of pottery, were recorded in Ibadan in a facility provided by the University of Ibadan, Department of Archaeology and Anthropology. One liter floatation samples were taken from all excavated levels and features. The floatation samples were taken across the level before excavation began. All the floatation samples are stored at Ibadan for future macro-botanical analysis. Soil samples were taken at the opening of new levels, always from the center point of the level. Charcoal samples were also taken for radiocarbon dating. The samples were collected at the trowel's edge, weighed, wrapped in foil, bagged in separate plastic bags, and labeled accordingly. The contextual information along with the condition and association of charcoal samples were described on a charcoal sample form. All the profiles were drawn, photographed, and described based on their texture, color, composition, compactness and cultural components.

Before we backfilled all the excavated units from the 2011/2012 season, we collected soil samples from units IO-B, IO-D, IO-C, and OO-A for pollen analysis. Samples of a minimum of 20 grams were taken with a trowel from the most preserved profile of the units, in 10cm intervals from bottom to top. Dr. Orijieme of the Palynology Unit, Department of Archaeology and Anthropology, University of Ibadan, collected the pollen samples, and analyzed the samples from IO-C (see Appendix A.1). After these samples were taken, all the units were backfilled. Excavated materials were curated in the Ile-Ife Museum and the storage facility at the Department of Archaeology and Anthropology, University of Ibadan. Selected samples of artifact classes were exported with the permission of the then Curator of the Ile-Ife Museum to Rice University in Houston, Texas USA for further scientific analysis.

IO-TP1

During the 2010 reconnaissance, a 1x1m test excavation unit (IO-TP1) was opened at Igbo Olokun to determine the subsurface potential of the site, and to obtain information about the depth, material, stratigraphy, and material culture at the site. The unit was located in the northwest section of the National Commission for Museums Monuments (NCMM) fenced plot. The southwest corner was the unit datum (Point of Origin) from which all depth measurements were taken using a level and string. Culture-bearing levels were excavated down to 55-70 cm depth, where sterile lateritic clay was encountered and excavated to 1.40 m. Although Frobenius reportedly encountered cultural layers underlying sterile laterite, we did not encounter any (Fig. 4.7). The top-most deposits were loose, sandy, organic-rich soil. A more compact deposit, reddish-brown in color, extended to a depth of 55 cm below datum. Concentrations of glass beads in the northeast sector at 30 cm depth and at 55-70 cm depth, where pottery, glass debris, and crucible fragments were also found, are likely all in the fill of a fairly recent pit extending almost to the surface. As explained earlier, this pit was detected only at 52 cm depth, so the density and type of cultural material in the pit fill compared to that in the deposits it was dug into cannot be determined. A charcoal sample from the pit area in the northeast corner at 35 cm depth produced a date of 130±30 BP, confirming the recent intrusion. Artifact counts for each excavated level and descriptions of each level are provided in Appendix A.2 and A.3.

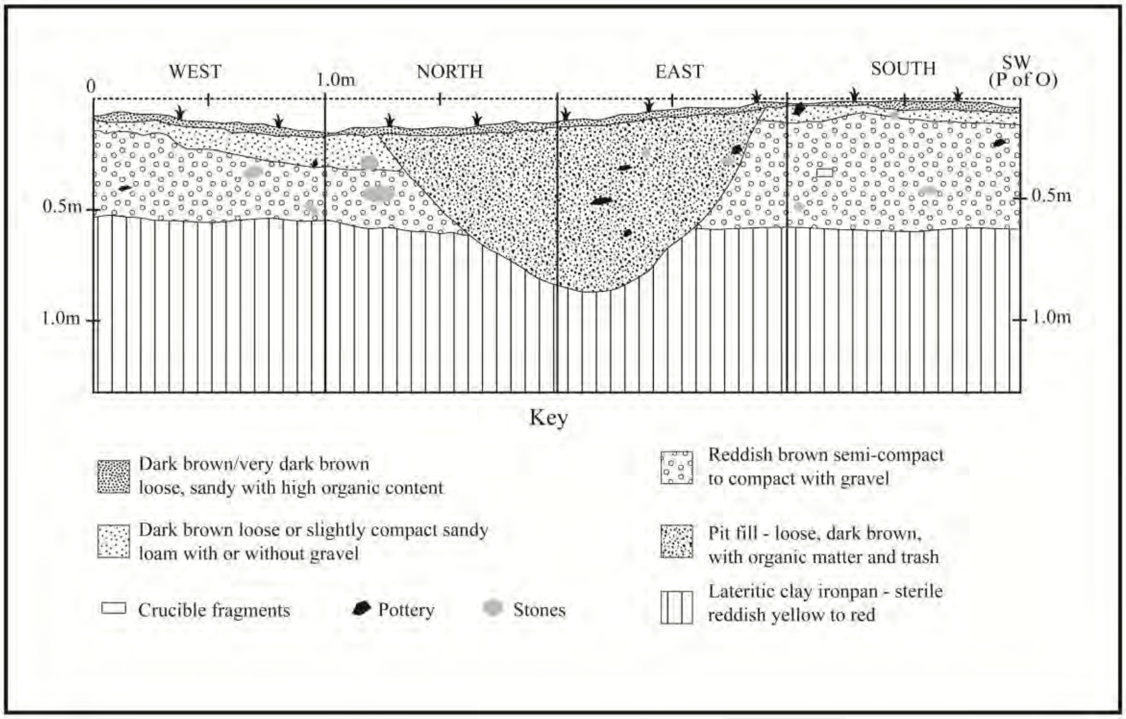


Figure 4.7: Natural stratigraphy of Unit IO-TP1.

Unit IO-A.

This 1x3 meter unit was located three meters south of IO-TP1 on a slightly undulating surface. The unit was intentionally placed close to IO-TP1 in order to recover more material relating to glass bead manufacture. The southwest corner was the unit datum (Point of Origin). Modern trash such as plastics plates and bags, fiberglass beads, bottle tops, metal straps, and broken necklace littered the surface of the unit. Crucible fragments and glass beads were also present on the surface. The unit was excavated through six levels to a depth of 70 cm below the surface (Fig. 4.8 and Appendix A.4).

The loose, loamy surface soil (Level 1) constituted a layer approximately ten centimeters thick that contained mixed recent and older cultural material. Underlying Level 1 was compact gravelly reddish,brown clay-rich deposit (levels 2 and 3) with patches of yellow and dark orange burned clay. This deposit continued, but with higher gravel content and a looser texture (Level 4) to a depth of 52cm below datum. Over 200 grams of burned clay was recovered from Level 4. Levels 3 and 4 produced the highest numbers of cultural materials, including glass (see Appendix A.5), but these were dispersed throughout the deposits without any detectable spatial focus or concentration. Level 5, which began at approximately 50 cm depth, was complex, with areas of lateritic clay with a high gravel content in the north and south, and an area with lower gravel content in between. At the north end of the unit, a layer of moist, very dark deposit associated with a pit that disappeared into the NE corner extended along the west wall, where it overlay gravelly sterile clay also excavated as Level 5 (Figure 4.9). Archaeological materials decrease drastically in level 5, and no material culture was recovered below the first 5cm of the level. The sterile, gravel-rich ironpan at the bottom of Level 5 was so hard as to be almost impenetrable. Similar, extremely compact lateritic clay deposits are found throughout Ile-Ife. This gravel-rich soil differed from the smooth-textured lateritic clay encountered in IO-TP1 only three meters to the north, and IO-TP1 did not show any sign of the very dark moist level in the north of IO-A.

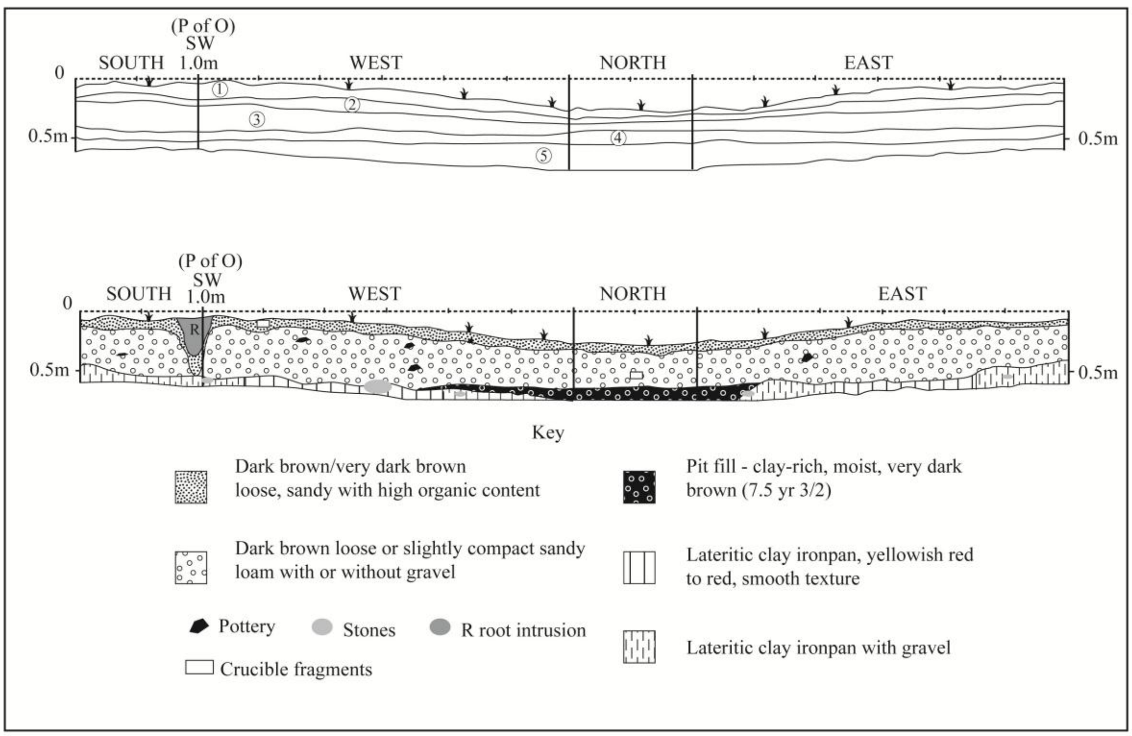


Figure 4.8: Natural stratigraphy and excavated levels of Unit IO-A

Excavated levels 1 through 5 yielded materials of industrial activities including ceramic cylinders, ceramic discs, crucible fragments, glass beads, and vitrified production debris (VPD); a single unfinished quartz stone bead was recovered from level 3. Pottery was also common to all the levels, although in varying frequencies. Appendix A.5 presents the artifacts recovered from each excavated level in unit IO-A.

Figure 4.9. Unit IO-A at sterile, showing dark fill in north, gravel-rich and smooth-textured lateritic clay ironpan in north and south, respectively.

Unit IO-B

Unit IO-B and its extension, Unit IO-D, were located approximately 20 meters east of IO-TP1 and unit IO-A (Fig. 4.1), in an area with few surface materials other than modern trash. IO-B measured 1x3 meters, and was excavated before extending the excavation by 1 meter to the west (Unit IO-D), creating a final unit measuring 2x3 meters. The unit was placed to examine the extent of glass production debris and to sample subsurface deposits in another area of Igbo Olokun. The unit datum (Point of origin) was placed in the southeast corner. Both IO-B and IO-D share similar stratigraphy and several pit features – two intersecting pits in the northern half of the units and one in the south (Fig. 4.10).

In Unit IO-B, Levels 1 and 2 consisted of loose sandy soil with a lot of organic content as well a modern trash. (see Appendix A.6 for a detailed description of the excavated levels). Level 3 was a loose, brown deposit that also contained modern trash. It was restricted to the southwestern quadrant of the unit and is likely related to the pit fill in the southwest corner. This pit was not detected until the lateritic clay into which it was dug, appeared at 70 cm depth. The top layers of this pit may be the source of the modern trash, such as rags and plastic, that were recovered from levels 1-4, but this is not certain. Levels 4 and 5 extended from approximately 25 to 50 cm depth and consisted of a semi-compact reddish brown loam that contained variable amounts of gravel. The western profile (Figure 4.11) indicates that the more gravelly and artifact-rich deposits in these levels were in the center-south area above the lateritic clay basement. To the north in the profile, these levels are more homogenous. The southern heterogeneous deposits, with their mixture of darker organic soil, may relate to either the southwest pit fill or a separate pit fill event. In the northwest corner, in Level 6 at 70 cm depth, a darker, moister deposit was encountered that would prove to be the fill of two intersecting pits (1 and 2). Elevated artifact content also announced the pit fill (Figure 4.12; see Appendix A.5 for the artifact yield from each level). Moist, dark, clay-rich deposit then appeared over the entire unit and was excavated as Level 7. Underlying Level 7 in the south sector was sterile, lateritic clay identical to that encountered in IO-TP1; it was not excavated. The pit mentioned earlier (Pit 3) had been dug into the southwest corner. A fourth pit disappeared into the southeast corner. In the north, the fill of the intersecting pit features was excavated as Level 8 (Figure 4.13). The moistness of the deposits may result from proximity to lateritic clay, presumably because drainage is blocked. It characterizes the fill of pits dug into laterite and deposits directly above laterite. The bottom of Pit 1 was reached at 132 cm. Excavation of Pit 2 was stopped at 1.51 m due to space limitations. It appeared to penetrate further into the western profile, which prompted the decision to extend the unit 1 m west, to better investigate the pit feature.

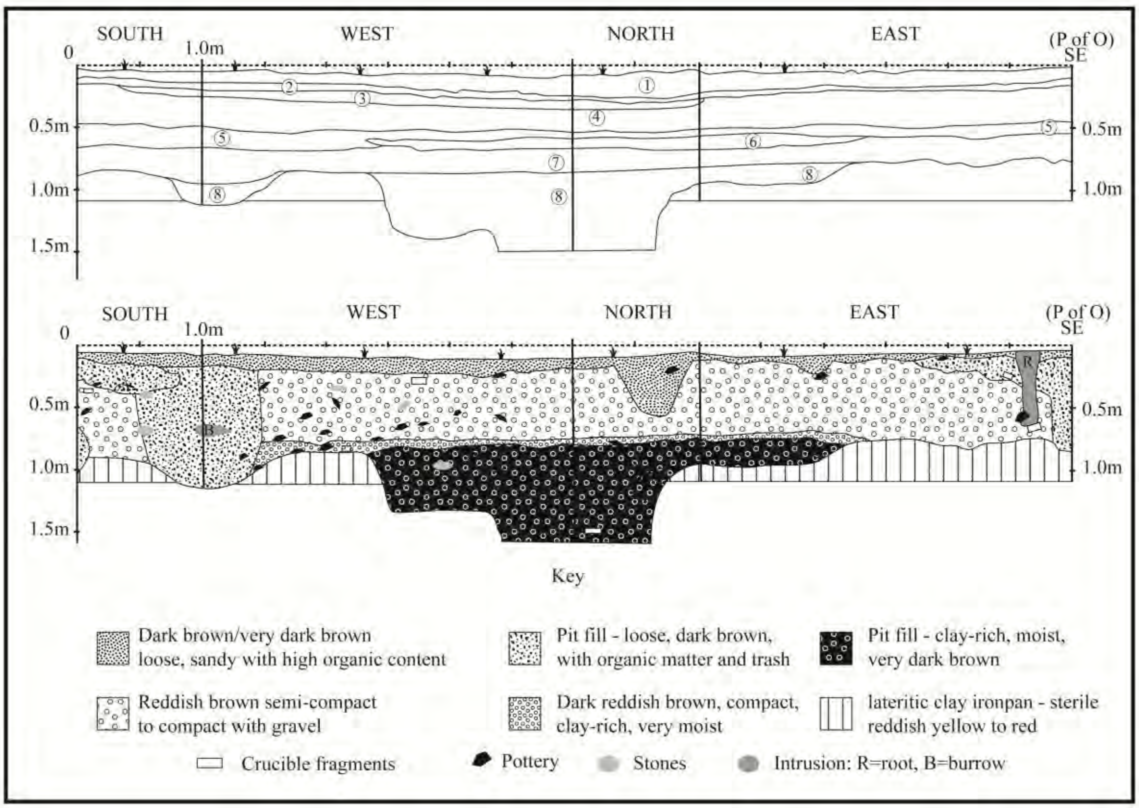


Figure 4.10: Natural Stratigraphy and excavated levels of Unit IO-B

Figure 4.11. Unit IO-B West wall, showing darker, gravelly deposits above the ironpan and more homogeneous deposits to the north above the pits.

Figure 4.12. Artifact concentration in the fill of Pit 2.

Figure 4.13. The fill of the intersecting pits 1 and 2 was excavated as Level 8 in Unit IO-B.

Unit IO-D

The surface level (Level 1) of IO-D was a sandy, loose, dark-brown, organic-rich soil that extended down 10-15 cm (Figure 4.14). In level 2, a pit feature with very soft fill appeared in the south end and continued down to 1.06 m, through Levels 3-7 (Figure 4.15). This was the continuation of the pit found in the southwest corner of IO-B (Pit 3). In level 3, at a depth of 35 cm along the west half of IO-D north of the pit just described, an area of reddish deposit was bounded to the east by a grayer, gravelly deposit that was very compact and hard to dig. The reddish soil may represent a large, shallow pit (Figure 4.15) that continued through Level 5 (IO-D) and 6 (IO-B), ending at 65 cm. Levels 4 and 5 were compact, reddish-brown deposits extending to 65 cm depth that contained many small inclusions of burned clay. In Level 6, the western half of IO-B pit 1 appeared. As in IO-B, deposits near the underlying lateritic clay were moist and very dark reddish brown in color. The density of cultural material, including potsherds, glass, and crucibles, was highest in levels 4 and 5, although Level 6 yielded the greatest number of artifacts, as it contained a much higher volume of deposits (see appendix A.5 for artifacts recovered from each level). The bottom of Pit 1 was reached at 1.32 m. Pit 2, in the north, continued to 2.0 m, at which point excavation was stopped without reaching sterile (Figure 4.16). Pit 2 had the characteristic bell-shape described by earlier archaeologists. (Figure 4.17). The pit fill was excavated as Level 7. The contents were identical to the cultural materials found throughout the IO-B and IO-D deposits (Appendix A.5), and were not found in notable concentrations. There is no indication that the materials, which included potsherds, crucible fragments, glass beads, and glass debris, were in primary deposits. There is no clue as to the reason the pits were originally dug and filled.

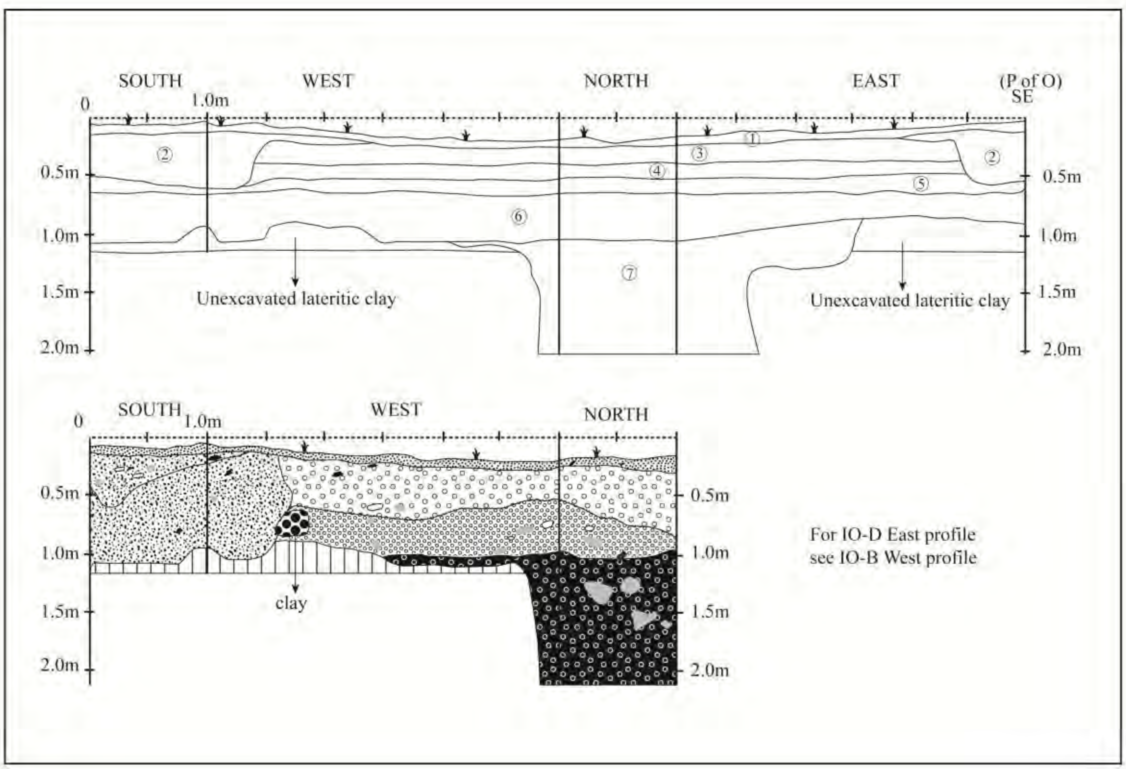


Figure 4.14: Natural Stratigraphy and excavated levels of Unit IO-D. For key, see Figure 4.10.

Figure 4.15. Pit 3 first appeared in level 2 at the south end of IO-D. In Level 3, a softer, semicircular area can be seen in the west, surrounded by grayer, gravel-rich deposit.

The depth at which Pit 2 originated was difficult to determine, even though it was cut by the north wall of the unit. The north profile does not reveal any obvious evidence of the origin, although it is clear that pit 2 was dug into Pit 1 (Figure 4.16). The origin depth of Pit 1 is similarly unknown. A radiocarbon sample from 1.43 m depth in Pit 2 produced a radiocarbon date of 70±30 BP indicating that the fill occurred relatively recently. Another sample from 70 cm. depth in the same pit produced a date of 840±30 BP, clearly indicating the mixing of older and more recent deposits in the pit.

Figure 4.16. Pits 1 (central), 2 (north) and 3 (south) in units IO-B and D.

Figure 4.17. Excavation of Pit 2 in IO-D, showing undercutting into lateritic clay.

Unit IO-C

This 1x3 meter unit was placed 10m northwest of IO-TP1, outside the NCMM property boundary where three slightly elevated areas in a U shape suggested a possible collapsed mud structure. There were surface finds of glass beads, pottery, and crucible fragments. Unit IO-C was located about 45 meters from Irebami Lane 7 and 80 meters south of the Esimirin floodplain. The excavation was intended to assess the kind of subsurface materials in the area beyond the NCMM plot. Unit datum was located 25 cm from the southeast corner. The excavation went down to approximately 135 cm below the point of origin through seven excavated levels (Fig. 4.18; Appendix A.7).

Dark, loose topsoil (Level 1) formed a surface layer around five to ten centimeters thick. Level 2 was similar, but lighter in color. Both Levels 1 and 2 were very dry and almost powdery in nature and yielded modern trash and the remains of tubers (cocoyam *Colocasia esculenta*), which points to farming disturbance. A chunk of decayed concrete possibly from initial fencing of the NCMM plot was encountered at 27 cm depth. Levels 3 and 4 were compact, moist deposits, with a reddish tint contributed by what appeared to be small, fired clay fragments – perhaps fragments of the basal lateritic clay? The level 4 deposits were very compact in the south, but softer towards the center and contained a high density of glass beads, glass debris and crucible fragments (see Appendix A.5). Level 5 deposits also produced notable numbers of beads and debris, but this level was much thicker (35 cm) than Level 4. It was moist, very compact, with lots of tiny specks of charcoal. Level 6 was also moist, darker, and had lots of reddish clay specks (Fig. 4.19). At approximately 1.20 m depth, sterile lateritic clay appeared unevenly in the north and southwest, and the depressions in the ironpan had very dark, moist fill (level 7) that contained artifacts. A charcoal sample from 1.30 m depth in level 7 produced a 14th century ^{14}C date (570±30 BP). Excavation ended at a maximum depth of 1.35 cm (Fig 4.20).

All levels in the unit produced significant numbers of artifacts, including glass beads, glass debris, and crucible fragments, which suggests that considerable churning of deposits has occurred. There is no concrete indication that any of the artifacts are in primary deposits.

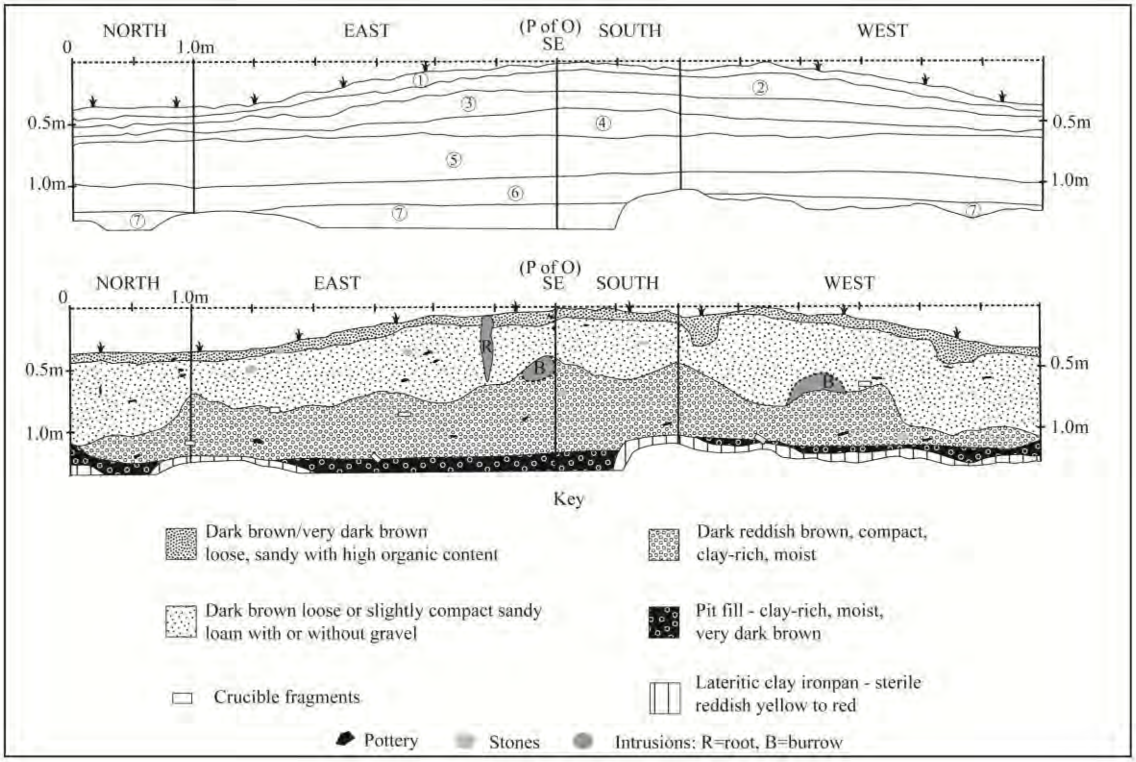


Figure 4.18: Natural Stratigraphy and excavated levels of Unit IO-C.

Figure 4.19. Lateritic clay in the southwest corner of IO-C is overlain by dark, moist deposits with red clay inclusions (level 6). The channel cut into the ironpan is visible and filled with dark moist deposit (level 7).

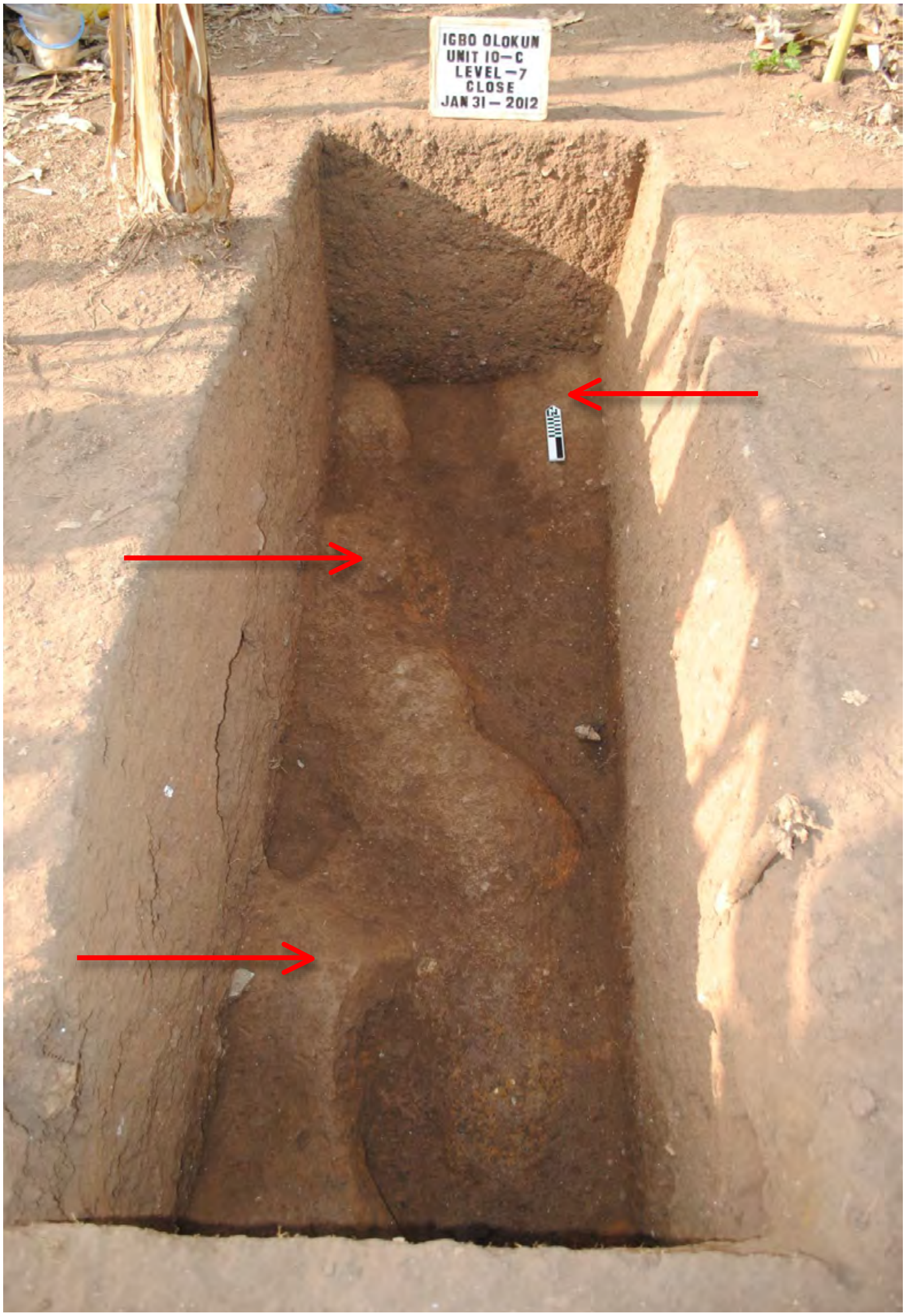


Fig. 4.20. Bottom of Unit IO-C (Arrows point to the sterile ironpan).

Unit IO-E

Established near a house at # 7 Lane 5 Irebami, in the backyard of Ms Tawa who graciously allowed us to dig there, unit IO-E was located at about 200 meters south of the NCMM plot where units IO-A, B, C, and D were excavated. This unit was excavated to check if debris from the glass industry extended this far. The decision was made in line with the evidence of artifact scatter observed on the street during our pedestrian survey of the vicinity. These artifacts included: pottery, ceramic cylinders, crucible fragments, glass debris, and glass beads.

This unit measured 2x1 meters and was placed at the center of a slightly elevated surface, with the point of origin in the southwest corner. The excavation revealed a shallow deposit through three excavated levels that overlay uneven ironpan that had been cut by shallow pit-digging (Fig. 4.21; Appendix A.8).

Levels 1 and 2 were loose, friable, dark, loamy sand. The deposit was fine and powdery with minimal gravel content. The deposits contained a large amount of modern trash, some mortar and pottery coated with cement on the outside, and significant numbers of potsherds, glass beads, and crucibles. Level 3 extended from 30 cm depth to between 42 and 73 cm, where uneven lateritic clay was encountered. In certain areas, especially the east, this level had a high gravel concentration where it overlay a very gravelly ironpan (Fig. 4.22). Artifact yield was low (Appendix A.5). The ironpan was presumed to be sterile and was not excavated.

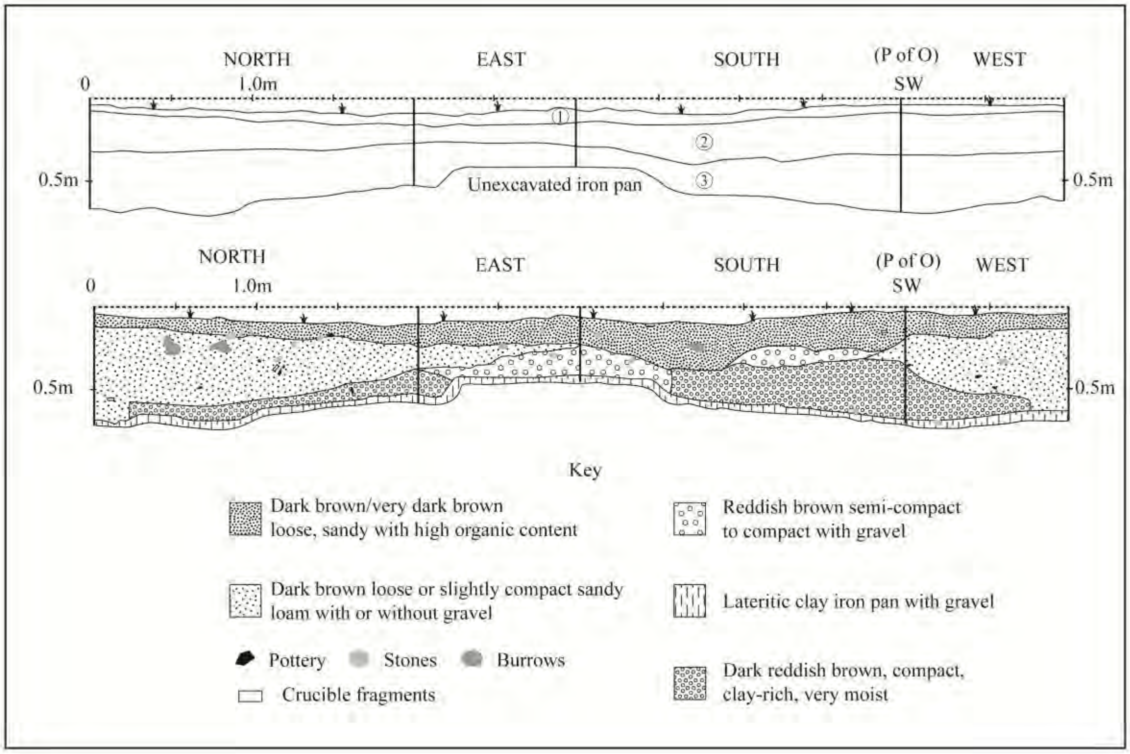


Figure 4.21: Natural Stratigraphy and excavated levels of Unit IO-E.

Figure 4.22. IO-E north profile, showing uneven surface of ironpan at closing.

Unit OO-A

Placed within the compound of Mrs. Adebowale at house number 16 Ooni Ilare Street, Ile-Ife, unit OO-A was about 1.5 km southwest of the preserved NCMM plot and about 20 m away from the ruins of the Ife city walls. The choice to locate the unit at this location was to test whether or not the Olokun industrial area extended farther southwest as suggested by historical memories by the contemporary inhabitants of Ile-Ife. Also it was hoped that materials from unit OO-A might present an opportunity for comparison with artifacts from other units for site typology, chronology, and material differentiation.

Unit OO-A measured 1x2 meters and was placed in an area without surface artifacts, although there were possible remnants of potsherd pavements nearby. The unit datum was in the southwest corner. Unit OO-A was dug through 8 levels to a depth of 115 cm. Levels 1 through 7 were cultural levels, while level 8 was sterile. The details on the depth, characteristics, artifacts, and deposition of all the excavated levels and the natural layer are presented in Figure 4.23 and Appendix A.9.

The deposits in this unit presented some differences from those in the Igbo Olokun units. In general, the cultural material appeared to be domestic rather than industrial. Upper deposits (levels 1 and 2) were compact, loamy clay, rather than loose and sandy, and yielded abundant pottery, but only ten glass beads, and one crucible fragment. Ceramic disks were more common (for artifact yields by level, see Appendix A.5). The compact character of the surface level could have resulted from several years of walking over the current ground surface. No farming of any kind was going on at the site at the time of the excavation. Rather the open backyard was a passage with high pedestrian traffic. The roots of a nearby palm penetrated the deposits. Evidence of modern pit-digging was absent.

Level 3, extending for about 20 cm, to a depth of 57 cm, consisted of the reddish-brown clay-rich loam frequently encountered in the Igbo Olokun units; artifact yield was about half of that from the comparable volume of Level 2 deposits and included only one glass bead. Immediately underlying level 3 was a layer of compact, wet, yellowish clay, excavated as level 4. Laterite clay of this kind is used as flooring in Yorubaland. The presence of a charcoal-rich deposit with ash and pottery in the northeast corner just above level 4 supports the floor fill interpretation of this yellowish layer.

Level 5 was compact, moist, dark, reddish-brown clay with gravel inclusions that produced few cultural materials. At about 70 cm depth, there were three different deposits: dark, loose deposit in the southeast corner, possibly related to ash and charcoal-rich deposits and potsherd concentration along the east wall, extending to 95 cm depth; loose, gravelly deposit in the eastern half of the unit (level 6); red, compact, sticky clay with fewer artifacts in the western half of the unit (level 7); Where Level 7 continued under Level 6 in the eastern part of the unit, it had many white quartz inclusions. Immediately underlying level 7 was sterile, compact, lateritic clay ironpan with a high concentration of stone/gravel inclusions (level 8). The excavation ended at 115 cm depth.

Unit OO-A is the only Ile-Ife unit reported here to provide good evidence of a stratified sequence of primary deposits (Fig. 4.24). This gives confidence that the charcoal sample from 92 cm in Level 6 is associated with the earliest human activity at this location, in or on the red clay overlying sterile ironpan, most likely sometime in the 14th century (610±30 BP).

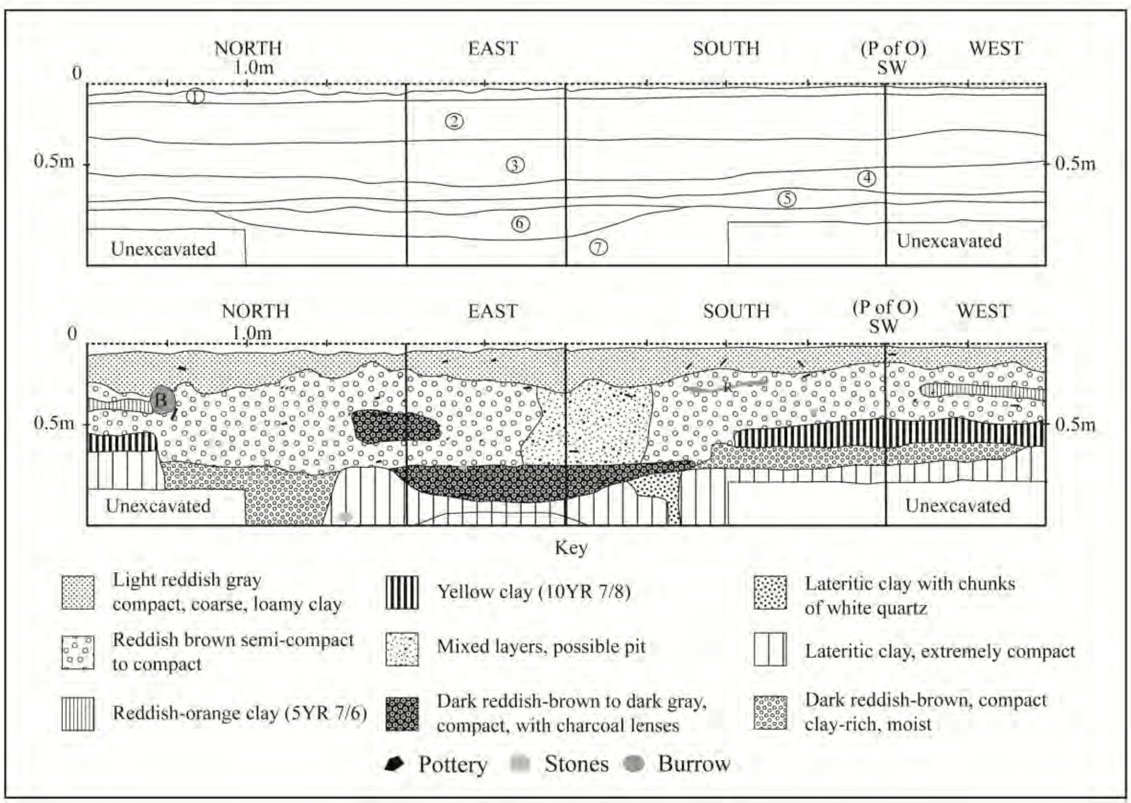


Figure 4.23: Natural Stratigraphy and excavated levels of Unit OO-A.

Figure 4.24. Unit OO-A west profile, showing stratified deposits; the yellow clay floor is clearly visible two-thirds of the way down. The profile is one meter wide.

Excavation at Igbo Rudi

IR-TP2. As mentioned earlier, Igbo-Rudi had never been investigated archaeologically. The site was selected for test excavation in November of 2010 when a crew including Dr, Ogunfolakan, Dr. Fleisher, Mr Olateju, and I carried out shovel tests at the site. The test excavation was intended to collect charcoal sample for radiometric dating, to examine the material culture at the site, and to check the potential of this area. The aim was to determine how the materials and the occupation at the site relate to classic Ile-Ife in terms of radiometric dating and material sequence.

Measuring 1x1 meter, IR-TP2 was excavated on a mound at the boundary of the sacred grove within a cocoa plantation. It was approximately 7 kilometers southeast of the units (IO-A, IO-B, IO-C, IO-D, and IO-E and IO-TP1) at Igbo Olokun. The point of origin was established in the northeast corner of the unit, from where all measurements were taken. IR-TP2 was excavated through eight cultural levels to a depth of 90cm below the surface. Level 9 was sterile. The excavation revealed five natural levels (Figure 4.25). Appendix A.10 summarizes the excavated levels. Materials recovered through the levels include pottery, ceramics disks, baked clay, animal bones, shells, tortoise shells, charcoal, iron objects, glass beads, and cowries (Appendix A.11).

Level 1 consisted of loose loam soil with high humic content, perhaps related to the cocoa plantation on site. Level 1 sealed an accumulation of a semi-compact clay loam devoid of humic content (levels 2 and 3) extending to a depth of 27 cm across the unit, although levels 3 seemed looser. Two animal burrows were encountered in this deposit: the first in the northern part of the unit and the second in the southern part. The burrows appeared first in level 2, and extended to a depth of 43 cm into of level 4. We recovered numerous palm kernel seeds from the southern disturbance, which suggest the presence of animal activities (e.g. giant grass cutter).

Levels 4 through 7 consisted of a domestic accumulation of mixed loose loam, fine sand, and clay loam matrix spread across the unit with varying thickness between 36cm and 54 cm. At about 38cm depth we encountered an ash concentration along the north profile, which spread a little along the east profile. No charcoal was observed in the ash concentration. At about the same level as the ash layer was a chunk of clay in the southeast corner.

Materials were well-preserved in the deposit. For example, in levels 5 and 6, between 42 and 57 cm depth in the unit, we recovered several whole snail shells with some near complete snail shells. These snail shells were mostly in association with larger pottery fragments (Fig. 4.26). Similarly, two well-preserved animal jaws were recovered at approximately the same depth. There was also a line of pottery protruding out of the southern profile (Fig. 4.27). The pottery line may suggest rapid accumulation of discarded material shortly after the area became a dumpsite.

Level 8 was a compact clay loam deposit with pockets of mixed matrix, extending to a depth of 73 cm. There was a drastic decrease in artifacts in level 8. The few materials recovered from level 8 came from the upper 6cm of the level. Underlying level 8 was compact homogeneous clay with no artifacts (level 9).

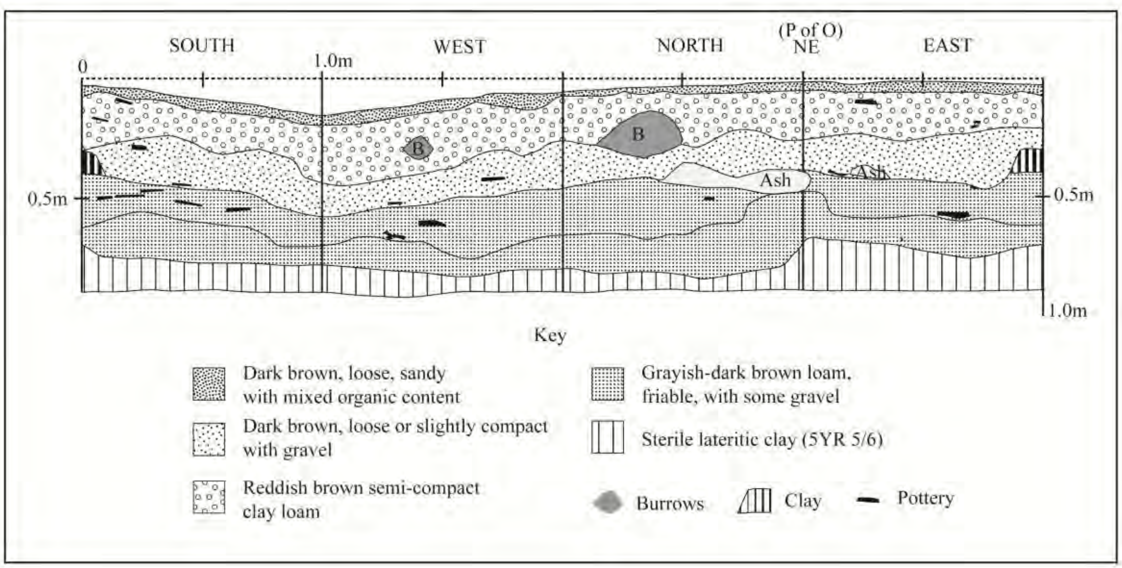


Figure 4.25: Natural strata of IR-TP2.

Figure 4.26: Plan of Level 4 of IR-TP2 showing snail shells and pottery (Note the burrow on the northern profile).

Figure 4.27: IR-TP2 showing the sterile and the pottery line at the base of the midden deposit on the western and southern profiles.

Summary of Depositional Events and Stratigraphy Across Units

The depositional events represented in the excavated units are consistent with depositional units reported from earlier excavations in Ile-Ife by Frobenius (1913), Eyo (1970), and others. Culture bearing deposits rest on top of, or in pits dug into, the natural lateritic clays that derive from the weathering of metamorphic basement rocks in the region. These reddish to orange-brown clays are extremely compact and may contain variable amounts of quartz gravel inclusions depending on derivation from, for example, gneiss or amphibolite (Ogunsanwo 1989). These sterile lateritic clays were encountered at a depth of 50-120 cm below the surface. As the natural soil in the region, these are a primary source of building material. The anthropogenic deposits that overlie them are compact reddish-brown deposits with artifacts and varying amounts of organic material. The clays and gravel in these deposits derive from the incorporation of the natural soil either as building material or as waste from pits dug through it. For a distance of 10–20 cm above sterile lateritic clay, the culture-bearing deposits may be very wet, reflecting lack of drainage through the compact underlying clay. Given sufficient time to dry out, these deposits change color from very dark brown to reddish-brown. The reddish-brown cultural deposits may be cut by recent trash pits or accumulations, which was the case in all the Igbo Olokun units. Only units OO-A and IR-TP2 seemed to have mostly undisturbed deposits.

The Igbo Olokun units provided evidence of multiple episodes of pit digging, some penetrating the sterile lateritic clay to an excavated depth of over 2 meters without reaching the pit bottom (IO-B/D Pit 2). The pit fill was very dark brown, but did not contain notable concentrations of artifacts or any clue as to the function of the pit. The pit appeared to have a passage leading from it into the northwest wall of the unit. At all Igbo Olokun units, glass beads, glass debris, and crucible fragments were recovered from all excavated levels, including pit fill and levels with modern trash. While there is no concrete evidence that any of these materials come from primary, undisturbed deposits, their abundance, especially at units within the NCMM fenced area, indicates that this was originally a production zone of glass workshops.

The depositional episodes and the kind of artifact yield in units OO-A and IR-TP2 suggest that they are not industrial sites. Most of the materials from unit OO-A point to a domestic function. The yellow clay floor, and two charcoal concentrations overlying each other in association with pottery concentrations indicate a domestic context. However this conclusion is offered with caution, as a 1x2 unit might not be enough to inform us definitively about the nature of the site. The unit yielded only a few glass beads and a lone crucible fragment. Only one glass bead was recovered from IR-TP2. Materials from IR-TP2 appear more preserved, larger, and seem undisturbed. The deposits included animal bone (100 g) and shell (119 g), plus pottery, all suggestive of domestic accumulation.

Site Chronology

During the excavations charcoal samples were collected for radiocarbon dating from all the units except for IO-E. So far we have analyzed six of the samples from units IO-B, C, D, OO-A, IO-TP1, and IR-TP2 (Table 4.1). All the analyzed samples came from the bottom of their respective units. Since most of the charcoal samples were small, AMS dating techniques were used. Beta Analytic analyzed all the samples (details from Beta Analytic are presented in Appendix A. 12a, b, & c). Although radiocarbon dating techniques remain an important tool for establishing chronologies for archaeological sites, they are not without limitations (S. McIntosh 1995: 59). These limitations can however be checked or reduced by first analyzing a range of samples, and second by critical comparison with relative dating (S. McIntosh 1995: 59) using ceramic sequences, for example.

Two of the dates indicate recent disturbances. In the case of IO-TP1 (Beta 297164), the source is a recent trash pit. As I will argue in Chapter 5, the presence of maize cob rouletted pottery in IO-TP1 is consistent with this date. Beta 329449 comes from the deep Pit 2 in IO-D, which also produced a date centuries earlier on another charcoal sample from the same pit fill in IO-B (Beta 319447). The latter date, calibrated to the mid-eleventh to mid-thirteenth century, is likely associated with the industrial glass-working debris. The deep pit was apparently dug sometime in the last three centuries and incorporated earlier material in the fill. I will argue in the next chapter that there is pottery in these units that includes diagnostic elements of "classic" Ife pottery dated to the 12th-15th centuries. Two other dates (Beta 3199448 and 3194550) from units IO-C and OO-A, respectively, fall in this same time frame and indicate that the earliest deposits in these units date to this period. The 16th-18th century date from Igbo Rudi TP2 is associated with a different pottery assemblage and represents a later occupation in the area.

Units	**Levels**	**Depth (cm)**	**Lab #. (Beta)**	**Radiocarbon Age**	**2 Sigma Calibrated Age 95%***
IO-TP1	5	35	297164	130±30	A.D. 1675–1942
IR-TP2	7	60	361087	280±30	A.D. 1498–1795
IO-B	7	70 (pit 2)	319447	840±30	A.D. 1058–1264
IO-C	7	130	319448	570±30	A.D. 1304–1423
IO-D	7	143 (pit 2)	329449	70±30	A.D. 1691–1924
OO-A	6	92	319450	610±30	A.D. 1295–1404

Table 4.1: Radiocarbon Dates from 2010-2012 Investigation at Ile-Ife and Igbo Rudi
*All dates calibrated with Oxcal 4.2, IntCal 13.

The two recent radiocarbon dates from TP1 and IO-D raised the question of whether, in these mixed deposits, the crucibles could be from a more recent period of glass-working. For that reason, we also submitted five crucible samples to the University of Washington Luminscence Dating Laboratory for direct dating using thermoluminescence (TL), optically stimulated luminescence (OSL), and infra-red stimulated luminescence (IRSL). Since luminescence dating determines the time elapsed since the last time the object was intensely fired, we assumed that it might be a good way to date glass production at Igbo-Olokun. The goal was for TL/OSL dating was to see whether the crucibles were more consistent with the classic Ife ^{14}C dates or the later dates. Dr. James Feathers' full report of the results is presented in appendix A.13.[2]

Results of the luminescence dating (Table 4.2) are clearly inconsistent with any of the ^{14}C dates. Three out of the five dates form a cluster around the mid-first millennium B.C. The other two samples are even earlier. One of the samples, UW3023, produced both a very early IRSL/TL date and an OSL date of the 14th century A.D. Although the 14th century OSL age is the most consistent with the ^{14}C dates, the TL and IRSL ages

[2] Dr. Thilo Rehren kindly underwrote the cost of these analyses.

from the same sample were older and “no other data from any other sample supported this younger age. It is therefore rather anomalous” (Feathers 2015: 4, Appendix 4. 13). However, two crucible fragments from the same context – Level 6 in unit IO-B/D – produced dates as much as a thousand years apart (UWA 3022 and 3023), which suggests that a critical approach to thinking about all these dates is necessary. We suggest that one avenue to investigate is the possibility that the crucibles originally lay in deposits that received higher levels of radiation than the soil samples submitted for dosimetry. Since the luminescence age is a ratio of the equivalent dose accumulated in the sample during the time it was buried to the dose rate of the radiation environment in which the sample was buried, this could be a significant factor. The soil samples came from the center of the level in which the crucibles were found, and we now understand that this soil may not have been the primary deposit for the crucibles nor even the secondary deposit from which they were recovered. The gamma dose rate to which the crucibles have been exposed since they were last heated may not be accurately represented by the soil samples analyzed. The fact that two crucibles from the same deposit produced such divergent dates may support the notion that they may have lain for different amounts of time in different radiation environments before being jumbled together in secondary deposits. Other explanations for sample UW3023 are possible. Dr. Feathers (2015 Pers. Comm.) suggests that probably “the TL and IRSL for that sample represent hard-to-bleach components that were not reset by firing and therefore overestimate the age.” He further explains that to make that argument would not account for the fact that the OSL produced older ages than expected for all the other samples.

Sample provenience	Lab #	Basis for age	Calendar date
IO-A Level 4	UW3020	TL/OSL	BC 1980 ± 300
IO-B/D Level 5	UW3021	OSL	BC 500 ± 220
IO-B/D Level 6	UW3022	IRSL/OSL	BC 540 ± 210
IO-B/D Level 6	UW3023	IRSL/TL	BC 1790 ± 490
IO-C Level 7	UW3024	OSL	BC 680 ± 210

Table 4.3. Summary of the results of the luminescence dating of Igbo-Olokun crucibles

No doubt, the luminescence results are confounding, as we lack comparative data that would confirm the use of crucibles and glass technology earlier than the late first millennium A.D. in the region. The question therefore is, what sense can be made out of the luminescence dates? We cannot provide an answer to this question at the moment. While further investigation will continue on the result of the luminescence dates, we will look carefully at associated materials, especially pottery, for additional chronological clues in Chapter 5.

Chapter Five

POTTERY

Introduction

This chapter reports the analysis of pottery assemblages from excavated units IO-B, C, D, and OO-A; and the pottery from TP 1 and TP 2, excavated in 2010. It describes attributes from the assemblage including rim form, decoration, paste, and surface treatment. These attributes are used to draw inferences about the assemblage and how it relates to other assemblages in Ile-Ife and surrounding regions. Although there is a long history of ceramic analysis in the Yoruba region, there is no consensus on pottery typologies. Work has often been carried out at two scales: either focused on particular sites or large-scale, "sub-regional" pottery classifications (e.g. Garlake 1977; Agbaje-Williams 1983; Eyo 1974; Soper 1983; Aleru 2006). Ogundiran (2002a: 95) has suggested that efforts to create a regional Yoruba pottery typology "eventually involve the cooperation of all the archaeologists working in the region." Indeed, Ekpo Eyo (1974a) was the first to attempt a region-wide study of Yoruba pottery when he considered the relationship between Owo, Ile-Ife, and Benin ceramics. However, this effort was not realized until recently (Usman 1998, 2002; Ogundiran 2000, 2002b). The work of Usman and Ogundiran combine primary data with existing archaeological and ethnographic data to refine ceramic zones for Yorubaland (see Fatunsin 1992 and Ajekigbe 1998 for ethnographic data on Yoruba pottery).

Yoruba pottery is often classified into a northern and southern region, each anchored with data from a major settlement, Old-Oyo and Ile-Ife. The characteristics of the northern Yoruba ceramic sphere are derived from the work of Frank Willett (1960) and Robert Soper (1983) in Old-Oyo, which identified two pottery phases: Diogun and Mejiro wares (Willett, 1960). Diogun wares are dated to the 12th century and characterized by brush or broom incisions, rocked comb-impressions, impressed arcs, knotted roulette and frond roulette. These wares have a sandy paste, and the color varies from fawn grey to brown. Mejiro ware is dated to the 14th century A.D. and characterized by carved roulette, snail shell marking, and maize cob roulette. Mejiro ware has a hard paste; the color is black, dark grey or light grey shading into a bluish grey, which is almost white (Willett, 1960: 75-76; Agbaje-Williams, 1983). Although Agbaje Williams (1983) argues that pottery decorative motifs such as brush-marked incision, snail shell impression and twisted string roulette were not restricted stratigraphically in the Old Oyo occupation, knowledge of the Old-Oyo pottery had helped to establish regional seriation for northern Yoruba region. This northern pottery sphere has been identified in the whole northern Yoruba region covering the period from 13th through 19th centuries (Usman 2001, 2003; Usman et al 2005; Aleru 2006).

In the southern ceramic zone, Garlake's (1977) pottery analysis from Woye Asiri and Obalara sites in Ile-Ife is of primary importance. These sites have been radiocarbon dated to between 12th and 15th century, and are suggested to represent domestic dwelling and "private shrine used in a variety of religious practices" (Garlake 1977: 94). Garlake worked with 166 complete vessels and over 3,000 rimsherds excluding those less than 2cm across, using a multi-variant approach. Based on the shape, decoration, and rim form, Garlake (1974, 1977) created a typology that identified and described 15 vessel types (App. 5.1). However the main characteristic of Ile-Ife pottery is different forms of carved and cord roulette, paint/slip, cross hatching, geometric, grooved, circular or pointed stylus, bosses and reliefs (Garlake 1977: 86-88). Following the forms and decoration of the pottery from Ile-Ife, Ogundiran (2000, 2001, 2002c) has identified a Ile-Ife ceramic sphere from settlements in south-central Yorubaland – especially in Ilare district.

Within these efforts to construct a regional understanding of Yoruba pottery, there is a strong emphasis on creating typologies. Although I agree with Ogundiran that efforts at a regional typology are needed for Yoruba pottery, a strictly typological approach will limit our understanding of the dynamism of Yoruba pottery. Such typologies may hide some of the nuanced technicalities involved in their making and perhaps use. In addition, typology tends to collapse variants into a single type, which prevents an understanding of variation within and between assemblages. For example, typology may consider decoration, form, and surface attributes to create a type but once created, it is difficult to assess how vessels within a type co-vary. These variations may be in the material used as temper and the degree of oxidation, which may reflect different techniques in producing vessels that seem typologically similar.

To this end, I adopt a multi-variant approach for analyzing the ceramics recovered from our excavations in Ile-Ife. Garlake (1977) was the first to use a multi-variant approach to study Ile-Ife pottery, with the ultimate goal to create a typology. In contrast, I intend to use multi-variant methods not to create a typology but to generate a database that can be arrange in different ways to answer a range of questions. Compared to typology-oriented approaches, a bottom-up multi-variant approach is open ended and more flexible. However, I should state that my own research has benefitted immensely from the previous studies by Garlake (1977), Agbaje-Williams (1983), Ogundiran (2000), Usman (1998), and Aleru (2000, 2006), all of which have been very useful for comparative purposes.

Thus, this chapter is not aimed at establishing a typology for Ile-Ife or Yorubaland, nor does it set out to seriate changes through time in Ile-Ife occupation, as the material currently available would not permit such analyses. What this chapter does is to describe Ile-Ife pottery as they occur at all the excavated units while exploring variations among the assemblages. In general, these are variations in space rather than time; this is because the assemblages all likely date to a single period, the 12th – 15th centuries, with only one assemblage (from TP 2) representing a later period (17th century).

The section that follows describes the procedures of recovery and recording of pottery during our excavations at Igbo Olokun. Then I discuss the variables used to record the sherds. A result of the analysis of the assemblages then follows. I present a discussion section that focuses on comparison of pottery among the excavated units, comparison with Garlake's work, and examination of Ile-Ife pottery regionally..

Recovery and Recording Procedures

Systematic recovery and data recording methods are fundamental to all subsequent interpretation. In this section, I describe the protocols used. Unlike many earlier excavations in Ile-Ife that yielded whole pots, no complete or near complete pottery was recovered from our excavations. We collected potsherds while excavating and while screening excavated deposits through 1 mm mesh. All sherds were placed in zip-lock plastic bags labeled with site name, excavation unit and level, artifact type, excavator's initials, and excavation date. Processing began with the washing, sun drying, and re-bagging of the sherds from the previous day's excavation. The Archaeology and Conservation Science students (class of 2012) of the Natural History Museum of OAU assisted with the washing, which was completed by local hires working under the supervision of a trained archaeology undergraduate senior.

For initial recording, all the washed potsherds from the same unit and level were sorted by part (i.e. rim, body, base, lid, and handle); each part class was counted and weighed. Lids and handles were rare. Bodysherds were further sorted into undecorated and decorated. Among the decorated sherds, those with a single motif were recorded immediately. All multiple motif bodysherds, rims, bases and handles were rebagged and relabeled separately for later analysis at Rice University. Because the sherd yield from the excavations was relatively low, 100 percent of the sherds recovered were analyzed and recorded. The sparse nature of pottery at the site is not surprising, as we are dealing with an industrial site, in contrast to domestic and ritual contexts in Ile-Ife where thousands of potsherds and numerous whole pots were recovered (Garlake 1974, 1977; Eyo 1974).

For the analysis, I recorded several variables, including decorative, morphological, and technical attributes. A summary of the variables and the codes used for the recording is presented in Appendix B.1. In the section that follows I discuss the variables and methods used in the recording of the sherds, beginning with the bodysherds with single and multiple decorative motifs, and then the rimsherds.

Bodysherds

Plain (undecorated) and single motif bodysherds from each excavation level/context were recorded in the field. After dividing the sherds into single motif groups defined by presence of slip, twisted cord, stylus, carve roulette, incision, impression, and appliqué or bosses, we recorded the number in each group. The different specific motifs are discussed below. Sherds from the same vessel were recorded as one and the number of the pieces in the group was noted. Recorded data for bodysherds with single motif is presented in appendix B.2.

Multiple motif sherds were recorded individually. In addition to decorative motifs, recorded variables included hardness, surface preparation, paste color, presence or absence of black core, and non-plastic inclusions (NPI). The data for bodysherds with multiple motifs is presented in appendix B.3.

Rim sherds

Rimsherds from each level/context were divided into larger (>3cm along largest dimension) and smaller (≤ 3 cm) sherds, with fewer variables recorded for the smaller sherds, since information on decoration and diameter, for example, is inevitably limited for such small sherds. The very thin walls of some of these smaller rimsherds indicate the presence of small and rather delicate vessels in the assemblage, so recording the sherds is essential to ensure their representation.

Overall, nineteen variables were recorded for larger rimsherds. These included provenience, rim diameter, rim thickness, rim form, lip shape, hardness, paste color, core, non-plastic inclusions (NPI), mica, surface preparation, presence of slip (surface treatment), and decorative motifs and their position on the sherd. Appendix B.4 and B.5 present the coded rim sherd data from our excavations for larger and smaller rims respectively.

Recorded Variables

Provenience. This includes site name (Igbo Olokun) and excavation unit (e.g. IO-A, IO-B, IO-C), and level/feature.

Rim diameter. The rim diameter, in centimeters, was measured by placing the arc of the lip of the rimsherd against a calibrated diameter chart (Fig. 5.1). In the case of a rimsherd with insufficient arc to estimate diameter, a "0" value was recorded.

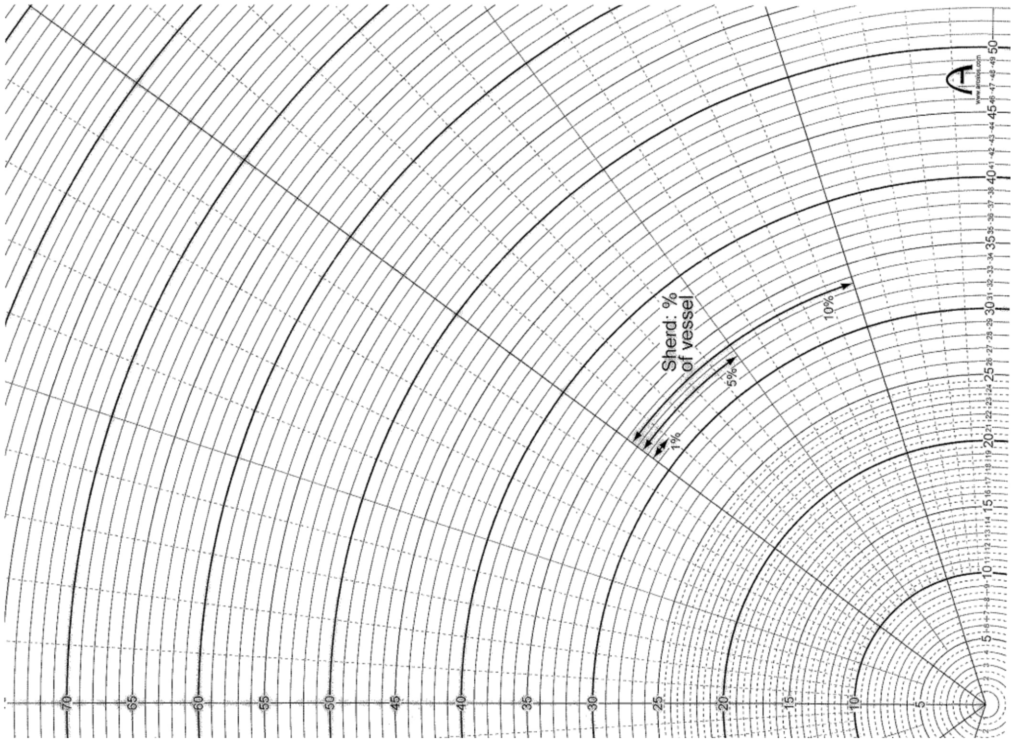


Figure 5. 1: Rim diameter scales. Note the rim percentage measurement.

Rim percentage. This variable determined percentage of the original rim circumference present. (Fig. 5.1). Where insufficient arc was present, this variable was recorded as "0".

Rim thickness. Rim thickness, like wall thickness, supports the strength of a vessel. The variation in rim thickness suggests different vessel size, form, and function (Rice 2005: 227). The rim thickness was measured in millimeters using digital Vernier calipers. The measurement was taken at the farthest point from the lip, that is, the point where there is distinct curve or angle. In the case of the rimsherds with no distinct curvature, I measured the thickness at any point along the lip/rim/wall area. This non-distinctive rim profile was common to vessels with simple rim. I describe rim types below.

Rim angle. This variable was recorded for simple rims to indicate how open or closed the vessel mouth is. A rim angle chart was used (Fig. 5.2) in which the double parallel lines represent the horizontal plane of the vessel rim

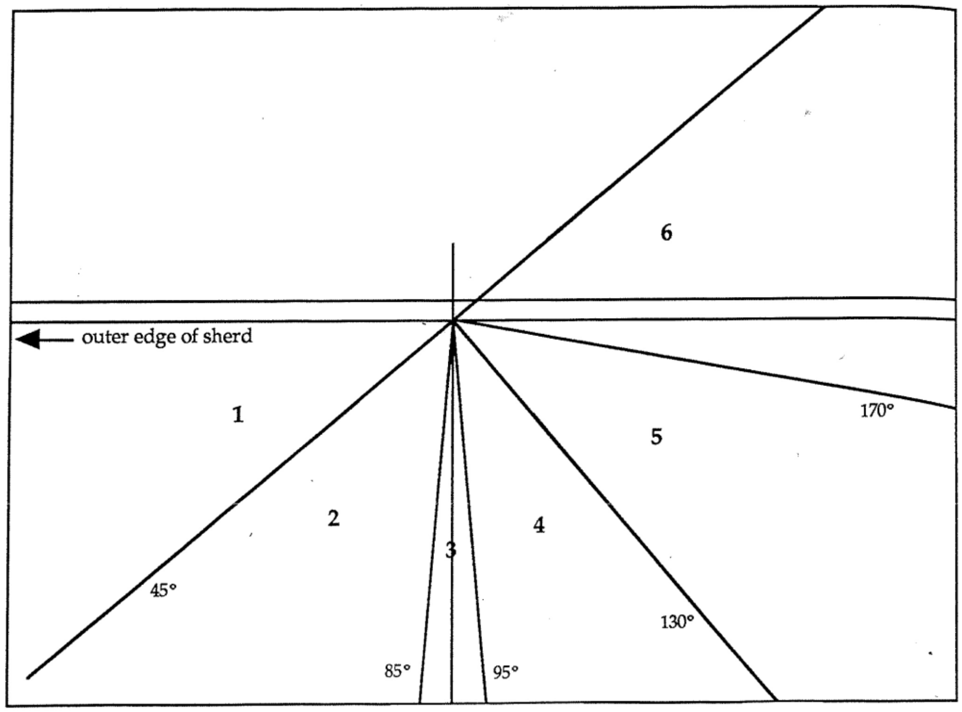


Figure 5.2: Rim angle scale. (from S.K. McIntosh 1995: 170, Figure. 3.6).

Rim form. Rim form refers to the rim profile, defined as the "shape of the rim in radial section" (S. McIntosh 1995: 141). The various rim forms encountered (Figure 5.3) have been divided into groups, with a numbering system that allows the expansion of the group as more excavations reveal additional variants: simple (101-104), thickened (201-204), carinated (301-303), ledged (401-404), short everted (501-505), medium everted (601-609), long everted (700-706), out-turn/T-rim (801-804), and beaded (901-902), potlid (1000). Rim forms that rarely occur were grouped into a general miscellaneous class (M1). A criterion for classifying the everted rims was their length, which was measured from the lip to the juncture where it joined with the shoulder or body of the vessel (Table 5.1)

Code/ Series	Rim form	Description
100	Simple	Shallow or hollow vessels with wide mouth. The rim is mostly non-distinguishable from the rest of the body. Mostly, they have rounded lip. Occasionally, the lip could be indented, flat, or beveled.
200	Thickened	Restricted or unrestricted vessels. The distinguishing element is the thickness of their rims, which set them apart from the simple rims.
300	Carinated	Usually restricted vessel. The lip could be rounded, tapered, or, raely, beveled. There is a rapid change in angle both inside and outside. These changes separate carinated from other rim forms.
400	Ledged	Always restricted vessels. The lips are usually rounded or tapered. Like the carinated, ledged may have change in the inside and outside angle. However, they are set apart by the bulge or cordon on their “shoulder”. There is a depression in-between the rim and the cordon. This depression in some case could be for holding a lip.
500	Short Everted	Shallow or hollow vessels with wide mouth and/or restricted neck. Length of the rim is 2cm and less
600	Medium Everted	Same as 500 but with rim length of between >2cm and 4cm
700	Long Everted	Same as 500 and 600. The distinguishing element is the length of the rim, which is usually >4cm
800	Out-turn/T-rim	Restricted or unrestricted vessel. Rim is almost out-turned or over-hanged. The T-rim team follows S.McIntosh terminology of similar rim at Jenne Jenno, Mali
900	Beaded	Rim is kind of rolled and close to the body of the vessel. Similar to 500, but mostly they are beaded rather than everted in appearance.
1000	Potlid	Mostly have rounded lip. Rim angle is 6, which is similar to shallow (almost flat) vessel. The concave or convex portion of they, where handle is attached, separated them from flat vessel.

Table 5.1: Summary description of the rim forms recognized from the assemblage

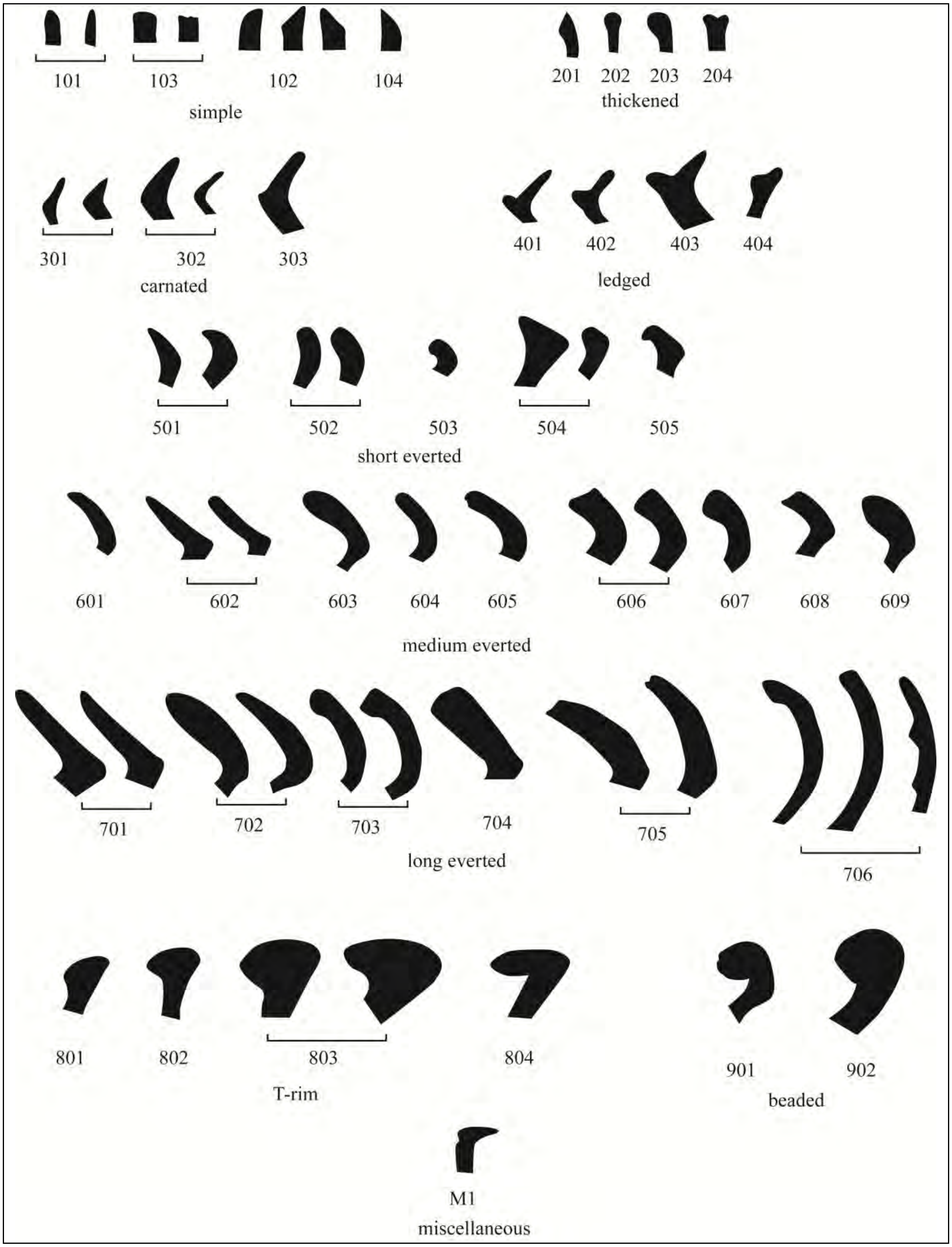


Figure 5.3: Ile-Ife rim forms recognized from the excavations at Ile-Ife (Not to scale)

Lip shape. Lip is a component of the rim, which is distinguished as "the edge or margin of the mouth of the vessel" (Rice 2005: 214). Figure 5.4 below presents the codes used for recording lip shape.

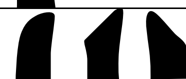
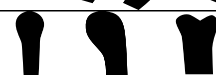
Code	**Description**	Example
1	Rounded	
2	Flattened	
3	Beveled	
4	Indented	
5	Thickened	
6	Tapered	

Figure 5.4: Codes for Lip Shape

Outside/inner surface treatment (Slip). This variable records the absence or presence of slip on both the outside and inner surfaces of a sherd. Slip is made by adding water to dry clay with mixture of some colorants, commonly, hematite (iron oxide) (Rye 1981: 41; S. McIntosh 1995: 135). Here, slip refers to application over a defined zone on the sherd, or over the entire surface. In prior studies of Ile-Ife pottery, slip used in this way has been referred to as "paint". The comparative pottery literature for West Africa (e.g., Connah, 1981, S. McIntosh 1995, Cisse, 2011), increasingly reserves "paint" for slip used to create designs on the pot surface. The nomenclature used here brings the usage for Ile-Ife pottery into alignment with the comparative literature.

The absence of slip was coded 0, while the presence coded as 1= red/orange (HUE 2.5YR5/6, 5/8; 5YR5/6, 2,5YR6/6, 6/8; 5YR6/6) and 2=brown (HUE 5 YR 5/3; 7.5 YR 4/3, 5/4). It should be pointed out that the brown slip might not have been an original slip color, as this could have been an effect of fire or smoke the pot was subjected to over time.. The presence of black carbon on the surface as a result of use on fire was noted in the comment column of the excel spreadsheet.

Hardness.This evaluates the impact-resistance of the sherd as well as the vessel from which it came. The hardness was evaluated by creating a fresh break with the use of pliers. While trying to create the fresh break, the degree of strength applied in the process was used to determine the hardness. Three categories were identified and coded as follows:. 1 = soft paste (easy to break with little or no effort), 2 = medium paste (greater pressure is needed to break), and 3 = hard paste (considerable force needed to break).

Paste color. Paste color was determined by visual observation of a fresh break. Four paste color categories were identified: Orange, brown, black/gray, and buff. Every third sherd recorded for each color category was checked on a Munsell color chart. This was to maintain some degree of accuracy and confirm the visual system. The color category derived from the Munsell Chart was confirmed with the Munsell color range derived by S. McIntosh (1995: 140), most of which matched. Table 5.2 below presents the visual color classes, their Munsell values, and codes.

Code	Visual Color categories	Munsell Values
1	Orange	2.5YR 5/8, 6/6, 6/8, 7/8; 5 YR 5/6, 6/8; 10R 6/8
2	Brown	5 YR 5/3; 7.5 YR 4/3, 5/4
3	Black/Gray	7.5YR 4/1, 6/1-2, 7/1; 10YR 3/1, 5/0-1, 6/2
4	Buff	7.5 YR 8/3-4; 10 YR 7/2-4, 8/3

Table 5.2: Codes and Munsell values for paste color

Core. Core refers to the presence or absence of a black/gray unoxidized core observed in fresh break, using Rye's categories (1981: 116) of different forms of oxidation. Code 0 was used for fully oxidized sherd, while codes 1 through 5 were used for other forms of oxidation observed. Figure 5.5 presents the different forms of oxidation recorded and their descriptions.

Code	Core	Description	Code
0	Fully Oxidized	Well fired, core completely turns orange	
1	Exterior Oxidation only	In the process of oxidation, half exterior oxidized and half interior unoxidized	
2	Interior Oxidation only	Reverse of 1	
3	Black Sandwiched	Black core line at the center of the section of a sherd	
4	Black/Gray throughout	Poorly (reduced) fired, no evidence of oxidation	
5	Sandwiched oxidation	Oxidized layer lies in the middle of the section in varying thickness	

Figure 5.5: Codes and descriptions for recording core

Non-Plastic Inclusions (NPIs). NPIs are defined as materials present in clay that do not shrink or deform as the clay dries or is fired. They can be non-organic or organic materials either naturally present or intentionally added by the potters in order to "modify the original clay's workability, drying, firing, and use-related properties" (Rice 2005: 408). NPIs identified in Ile-Ife pottery include quartz, sand, and grog (crushed pottery). Sand may be naturally occurring in the clay source. Grog is intentionally added by the potter. Since the quartz appears to have been crushed, it is more likely that it was intentionally added by the potter rather than occurring naturally. The NPIs were identified through visual inspection of fresh break, aided by, 10x, 20x, 30x, and 40x magnification hand lenses. In the case whereby more then one NPI type was observed, the main NPI was recorded as dominant with the second recorded as other; a code of 0 for other NPI indicates only one type of NPI was observed. . (Table 5.3).

Code	NPIs	Description
1	Quartz	Crushed quartz, which appears chunky and angular under a hand lens
2	Sand	Ranges from medium to fine grain. Usually rounded in appearance
3	Grog	Ground potsherds, which appear in distinctive colors in the paste. The color varies from orangish-red to black

Table 5.3: Codes and description of NPIs

Mica. Mica is a common element in Ile-Ife clay (Ige *et al.* 2009: 94) and may be useful in differentiating clay sources. This variable indicates the relative frequency of mica in the paste. The absence or near absence of mica was coded as 0. The near absence of mica was defined as a situation whereby it takes over 5 second to recognize mica from the surface/paste of a sherd. The presence of mica on the other hand was coded 1 through 3, representing high, medium, and low concentration respectively.

Surface preparation. The presence of smoothing or burnishing to create a more regular or less permeable surface was recorded. The marks from dragging of a rag or other material across the surface of a vessel helped to identify a smoothed surface. Burnishing also smooths the surface of a vessel but applying pressure with stones, bones, or seeds produces a shiny surface that reflects light. Other researchers (e.g. Agbaje-Williams 1983, 1987) have noted that burnishing is rare on Ile-Ife sherds, although post-depositional surface erosion may possibly play a role in making burnishing difficult to recognize. As opposed to a smoothed or burnished surface (code 1), a coarse or uneven surface, at times with voids, indicates no surface preparation (code 2). Heavy surface erosion (code 3) made the initial surface preparation impossible to detect.

Carved roulette decoration. Carved roulette decoration has been identified as significant and common signature of classic Ile-Ife pottery (Garlake 1977), so it is considered separately as a decorative category. Twenty-five different motifs were identified (codes 1-24 -Figure 5.6.), the majority of which correspond to or closely resemble the roulette patterns illustrated by Garlake (1977: 86 – reproduced here in Figure 5.7). Garlake (1977: 74) chose to record just two broad categories of carved roulette: ladder and non-ladder patterns. For Igbo Olokun sherds, the specific motif is recorded.

Position of carved decoration. The placement of carved roulette decoration is described by this variable: absent (code 0); present on lip (1), rim (2), rim and shoulder (3), rim, shoulder, and body (4), shoulder and body (5), body (6), neck (7), shoulder (8), interior (9).

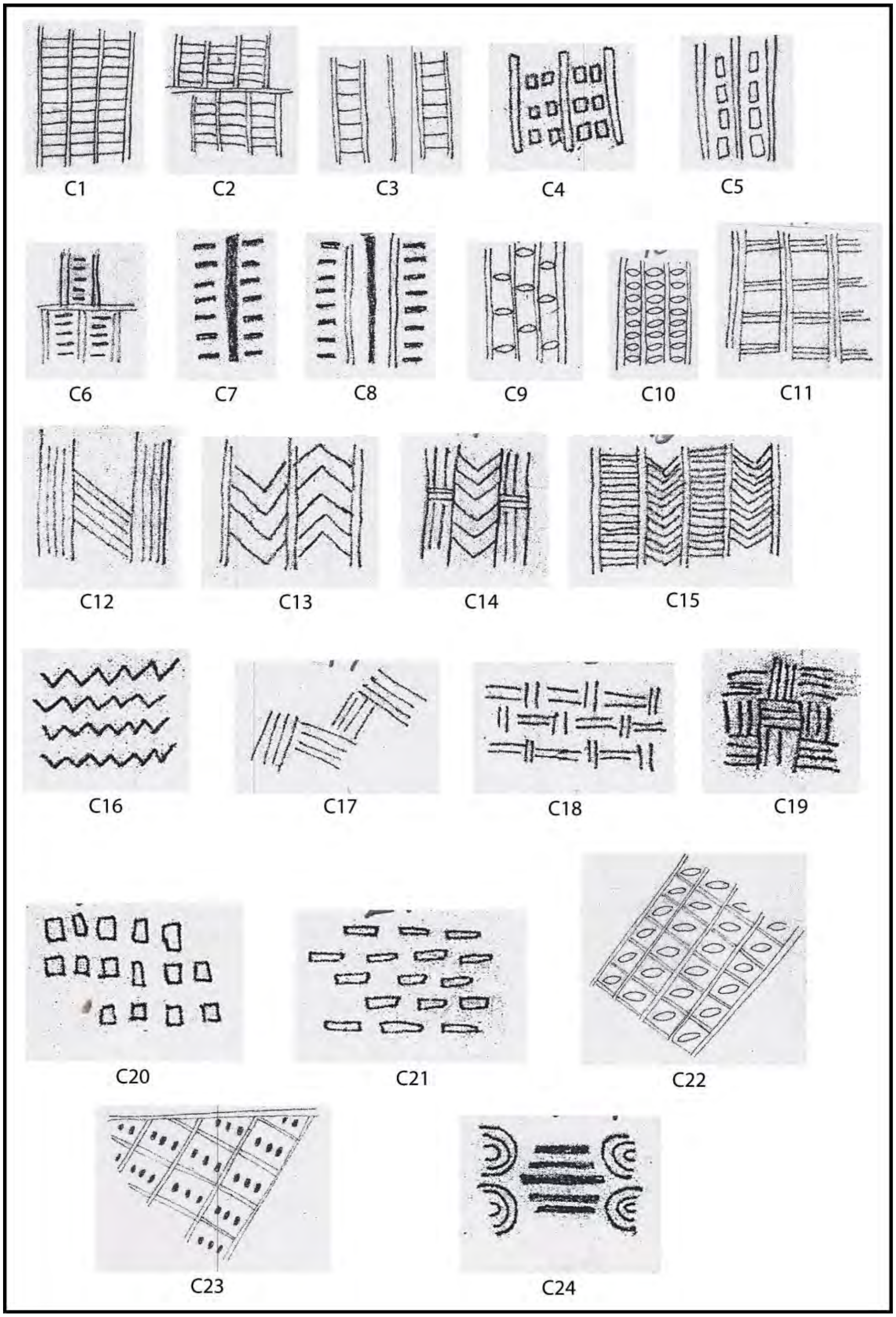


Figure 5.6: Identified carved roulette decoration from the excavations in Ile-Ife (Not to scale).

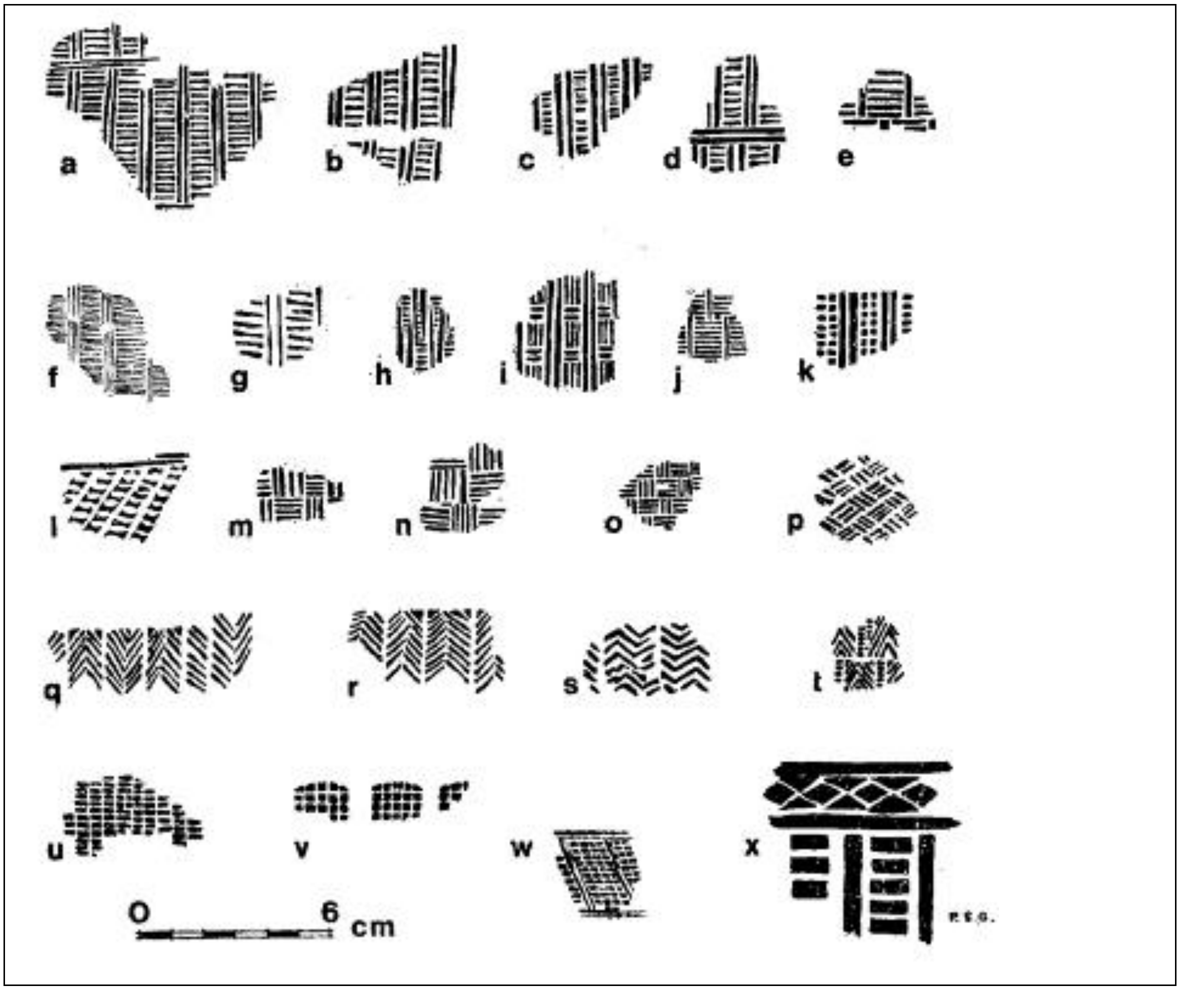


Figure 5.7: Ile-Ife carved roulette decoration recognized by Peter Garlake (1977: 86).

Other plastic motifs. Following Shepard (1974: 194-5), S. McIntosh (1995: 136), defines plastic decoration as any decoration technique that exploits the properties of clay by cutting or impressing the clay or by adding clay to the surface. Twenty motifs, in addition to the 25 carved roulette motifs already described, were identified and coded 1 through 20 (Figs. 5.8 & 5.9). Table 5.4 presents the codes and description of various plastic motifs. As shown in figure 5.8, some of the identified plastic motifs occur in the company of another. As indicated in table 5.4, bosses, raised, cordon, relief, applied were grouped into one motif class. We group these together because they all represent forms of motif that require additional clay strew as appendages on the vessel surface. Also the small size of the sherds was a disadvantage for us to identify them as individual motif.

Hopefully, future works might yield bigger sherds that will help to refine this class of plastic motif.

Plastic motif location. This variable concerns the placement of the other plastic motifs, using the same codes as Carved Roulette Decoration (Table 5.5). Code 10 was added to represent sherds with plastic motif located on the raised/cordon (Table 5.5).

Codes	Motifs	Description
0	None	No plastic decoration of any kind
1	Twisted twine Impression	Twisted cord impression may have resulted from rolling of single twisted cord or two/more twisted cords
2	Unidentified Twine Impression	Produced by forms of twine impression but the particular twine technique could not be identified. Occasionally, few resemble maize cob impression. However close examination proved otherwise
3	Unidentified carved Roulette	Carved pattern not fall in any of the identified forms, and not clear enough to form an independent class
4	Comb Impression	Regular dotted cells, which appear in straight, curved, or rocker patterns
5	Wavy Dragged comb	Produced by dragging of comb or other sharp object with multiple points in a wavy pattern of parallel, shallow incisions.
6	Fingernail Impression	Crescent shaped pattern, resulted from impressing of finger nails in a repeated sequence. The crescent could face any direction, and could appear individually or in a close series
7	Thumb Impression	Appears in dimple form. Mostly apply on bosses
8	Eye Impression	Series of two or three eye shaped impressions representing the pupil, iris, and eyelid.
9	Punctate (Angular)	Stabbing impression with angular stylus (e.g. triangle, trapezium)
10	Punctate (Circular)	Stabbing with a circular stylus to create a circular hole
11	Punctate (circular stylus)	Perfect circular outline created by impressing a circular stylus
12	Single Groove	A thin straight line, which lacks depth
13	Multiple Grooves	Thin, shallow multiple straight lines, oriented horizontally. Dragged comb
14	Channel(s)	One or more wide grooves. The major difference between channels and grooves is that channels are wider and usually have "U" shape. Created with blunt object rather than sharp or pointed object in the case of grooves

15	Incisions	This includes curved, slanted, and vertical incisions in different forms and patterns that are not covered by other incised categories.
16	Cross Hatched	Produced by dragging of shape object in both vertical and horizontal or slanted directions. Variant of this is similar to what Ogundiran (2000) called hyphenated incisions
17	Zig-Zag	Like wavy dragged comb. But rather than leaving a gentle curve slopes, they are pointed. Mostly occur in series rather than single pattern
18	Geometric	Crossing of two or more lines forming an angle other than those already describe above.
19	Perforated	Punched holes through the body of a vessel
20	Bosses/Raised/ Cordon/Relief/ Applied	Extra clay added to the surface of a vessel to form a particular pattern. The pattern could be zoomorphic, anthropomorphic, or geometric in nature. It also include ridges formed by raising of clay of the vessel instead of adding a new clay

Table 5.4: Codes and description of plastic motifs on the pottery from Igbo Olokun and Igbo Rudi, Ile-Ife.

Codes	Decoration location
0	None
1	Lip Only
2	Rim Only
3	Rim, Shoulder
4	Rim, Shoulder, and Body
5	Shoulder and Body
6	Body
7	Interior
8	Neck
9	Shoulder
10	Raised/Bosses/Cordon

Table 5. 5: Codes for decoration location on the sherds from the excavations

Figure 5.8: Plastic motifs on pottery from the excavations in Igbo Olokun and Igbo Rudi (1 = variants of bosses/relief/raised; 2 = variants of circular stylus; 3 = right – circular

stylus, middle & left – cross-hatched/hyphenated incisions; 4 = right & middle – forms of incisions, left – multiple horizontal grooves; 5 = right – fingernail in between raised/ridges, middle & left – variants of geometric; 6 = right perforated, middle & left – angular punctate).

Figure 5.8 (Cont.): Plastic motifs on pottery from the excavations in Igbo Olokun and Igbo Rudi. (7 = right - raised dots, middle – single groove, left & 8 right – variants of twisted twine; 8 = middle & left – variants of wavy dragged comb; 9 = right – wavy

dragged comb + red slip on the rim, middle & left – variants of comb impression; 10 = right – wavy dragged comb + multiple horizontal grooves/incisions, middle – slanted incisions + channel, left – incisions + circular punctate; 11 = right – cross-hatched + circular punctate, middle – raised + vertical incisions, left – fingernail + ridged/raised+ horizontal incisions)

12

13

Figure 5.8 (Cont.): Plastic motifs on pottery from the excavations in Igbo Olokun and Igbo Rudi. (12 = right – applied/cordon + horizontal grooves/incisions, middle – geometric incisions + applied, left – raised + vertical incisions; 13 = right – channels + twisted twine, left – raised/ridges + slanted incisions + red slip).

Figure 5.9: Variants of incised decorative motifs from our excavations

Result of the Analysis

The analysis is based primarily on the material recovered from Igbo Olokun units IO-B, C, D, and OOA in 2011-12, but material from 2010 test pits in Igbo Olokun (TP1) and Igbo Rudi (TP2) will be discussed as well. The variables recorded on rimsherds more than 3cm and those less than 3 cm across were combined for the analysis of rim form, rim thickness, paste, and non-plastic inclusions, unless otherwise indicated. While rimsherds smaller than 3 cm usually have very limited information on decoration, they provide data on these other variables and increases our sample size for them, an important consideration because we have so few rim sherds.

Overview description of the Assemblage

Although rimsherds comprise less than 5% of the pottery recorded, (Fig. 5.10), they provide most of the data on variables in the assemblage, given the recording procedures already described. Statistical analysis and meaningful comparisons from level to level or among units are hampered by the small sample size per level, and related levels have been combined to counteract the effect of sample sizes of less than ten rimsherds in a level. Some consistent general patterns emerge, and in this section, I describe the Igbo Olokun assemblage in terms of these.

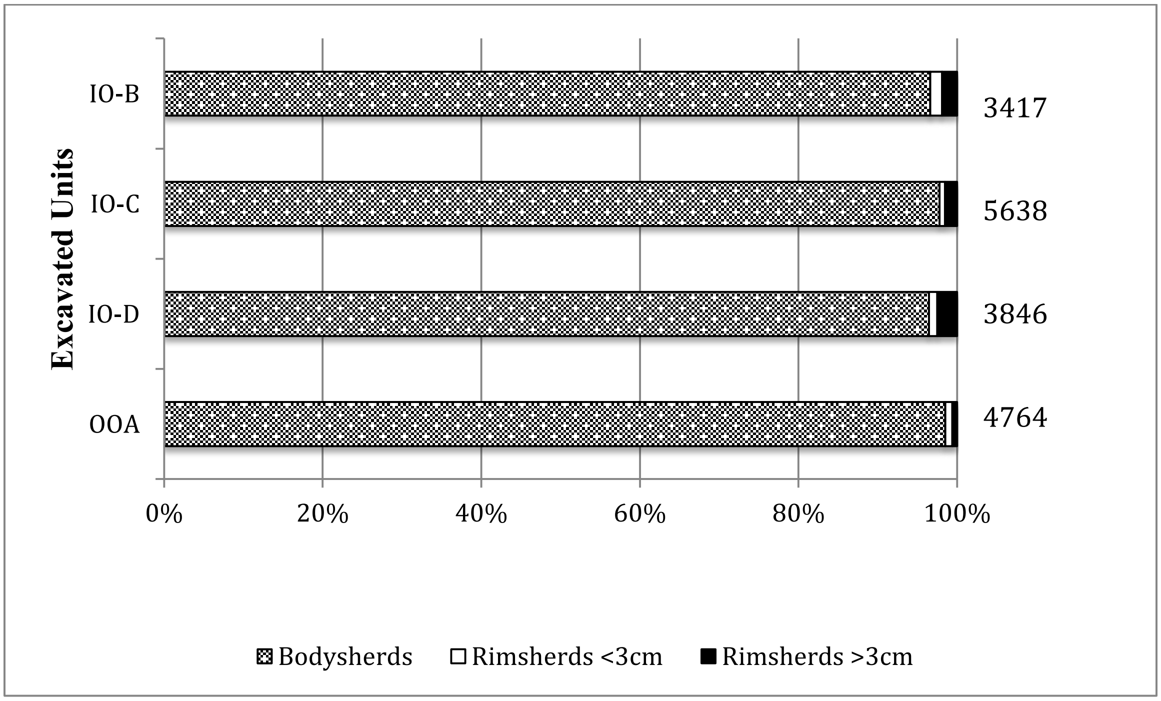


Figure 5. 10: Distribution of bodysherds and rimsherds across all units (potlids are not included in the chart because they are too small and will not appear on the graph)

Rim form

Simple and everted rims account for 60 to 90 percent of the rim types in all but one instance (Figs 5.11–5.14). The medium everted rims are the most common rim forms with frequency ranging between 25% and 75%. Within the class of simple rims, open rims dominate slightly over closed rims on average. Ledged and carinated rims seem to increase in frequency in the lowest deposits. The “other” category includes beaded, T-rim, and potlids, which occur in very low quantities. Rimsherds in each category are illustrated in Figures 5.15–5.21. The two recognizable pieces of potlids in the assemblage were identified with their nob-like handles not their rim form (Fig. 5.22). There is another possible handle recovered from feature 1 level 6 of unit OO-A (Fig. 5.22). The slight curvature of this ceramic suggests that it may have been an appendage to a vessel or some other ceramic object.

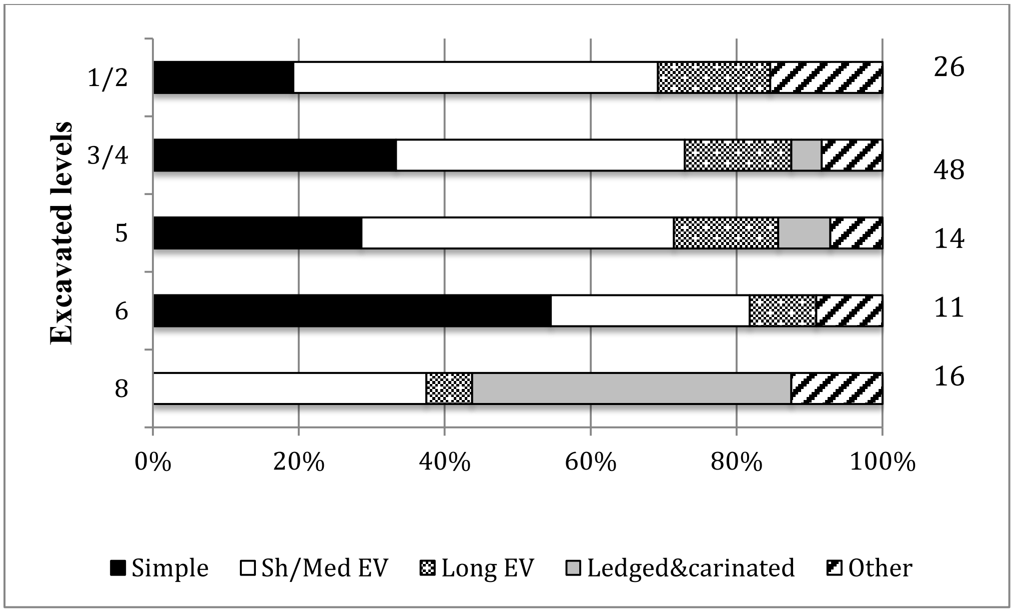


Figure 5.11: Distribution of rim classes from unit IO-B

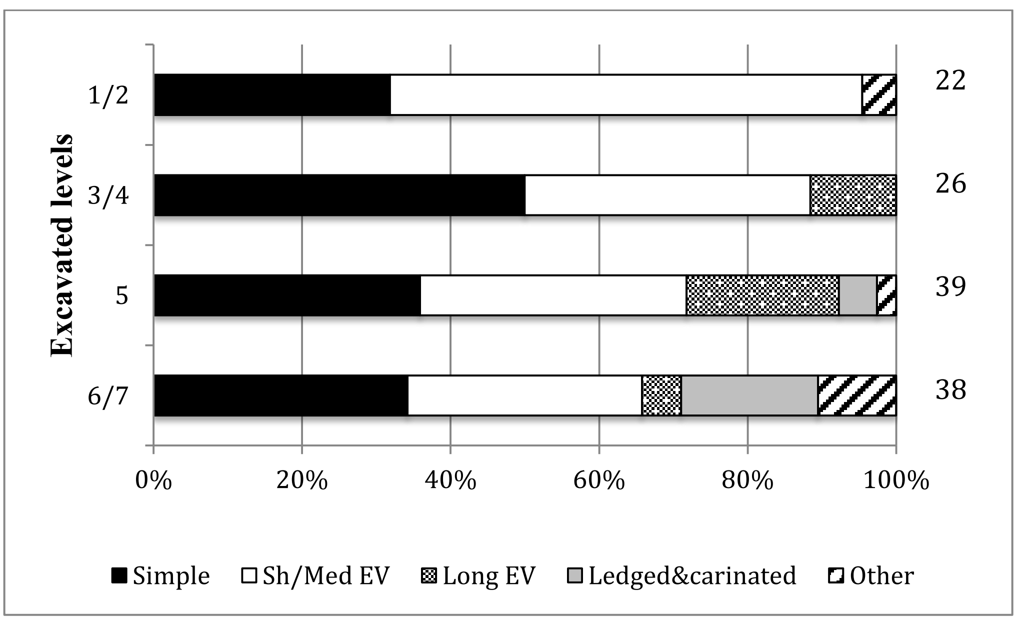


Figure 5.12: Distribution of rim classes from unit IO-C

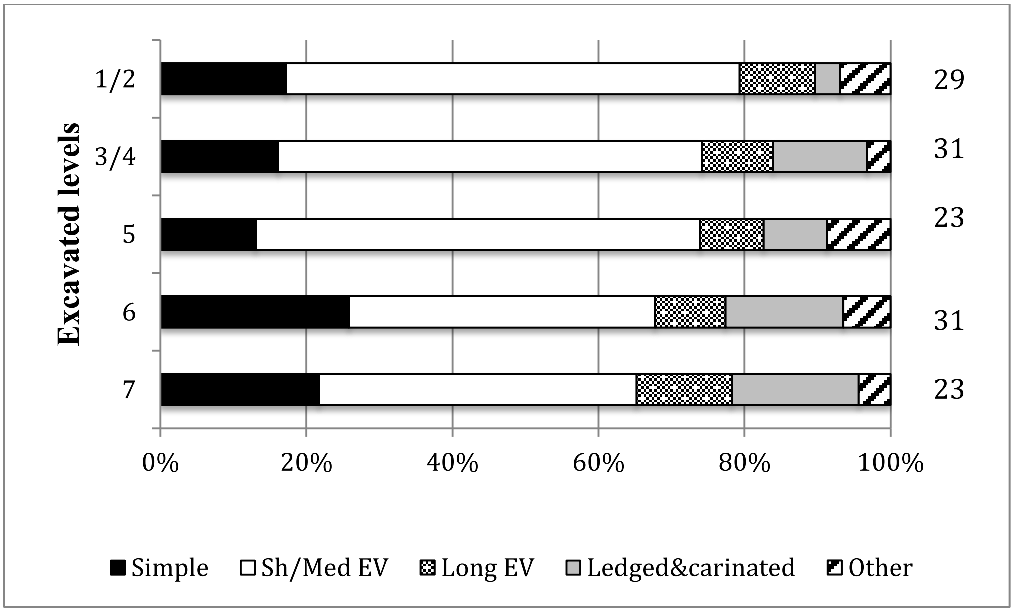


Figure 5.13: Distribution of rim classes from unit IO-D

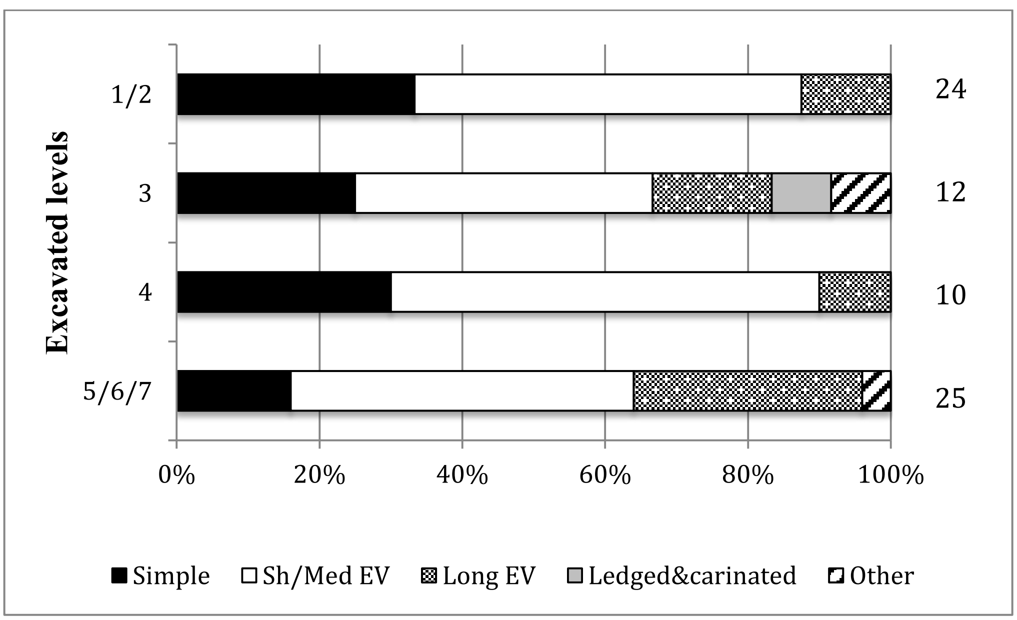


Figure 5.14: Distribution of rim classes from unit OOA

There is no significant change in rim diameter across units. Vessels with rim diameter between 10cm and 20cm are common to all the rim forms. Their percentage varies between 50% and 70%. Vessels with smaller rim diameter (i.e. <10cm) are restricted to vessels with short and medium everted rim form (Fig. 5.23).

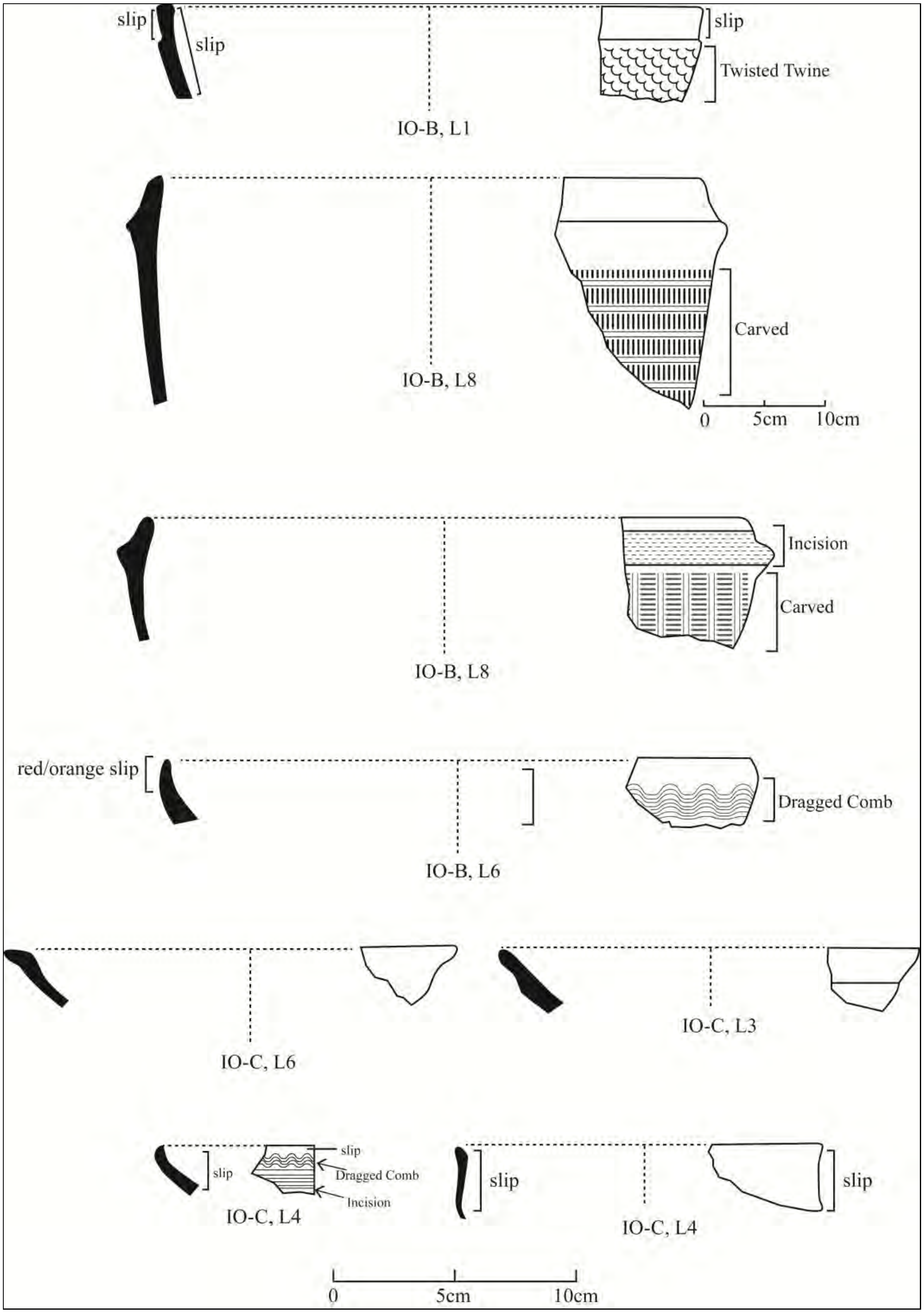


Figure 5.15: Major rim form class: simple open (unrestricted) vessels

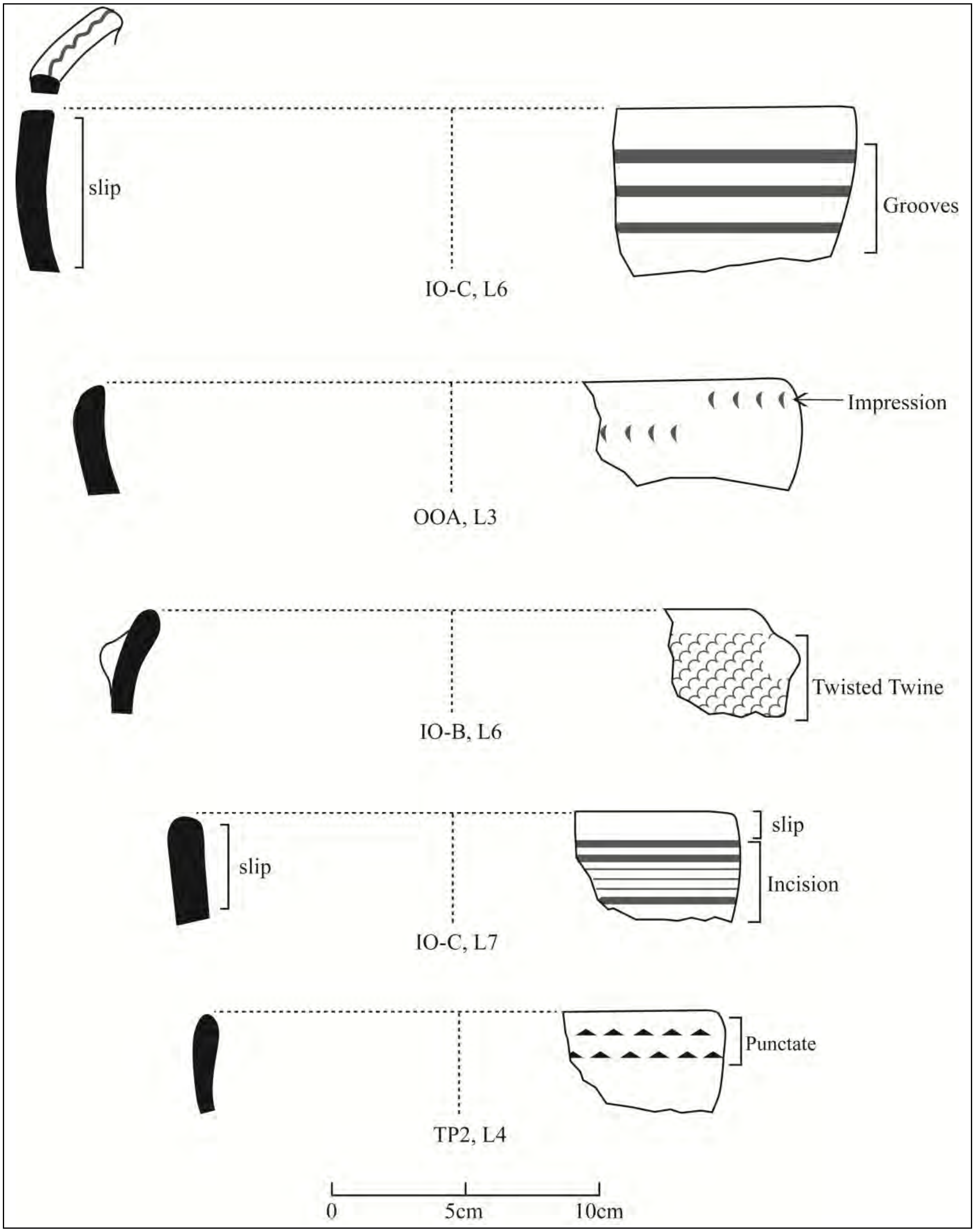


Figure 5.15 (Cont.): Major rim form class: simple open (unrestricted) vessels. What is the dark grey?

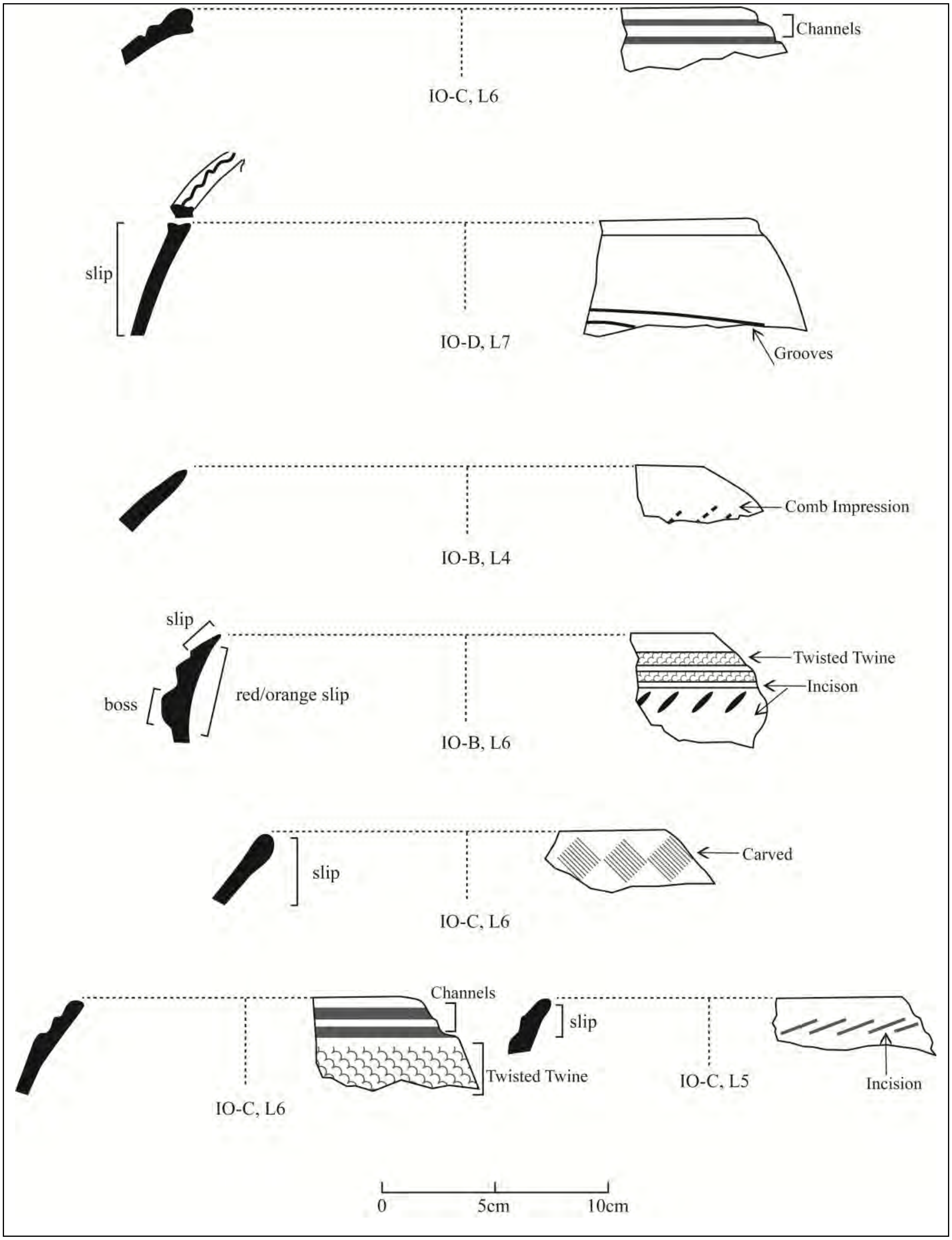


Figure 5.16: Major rim form class: simple closed (restricted) vessels.

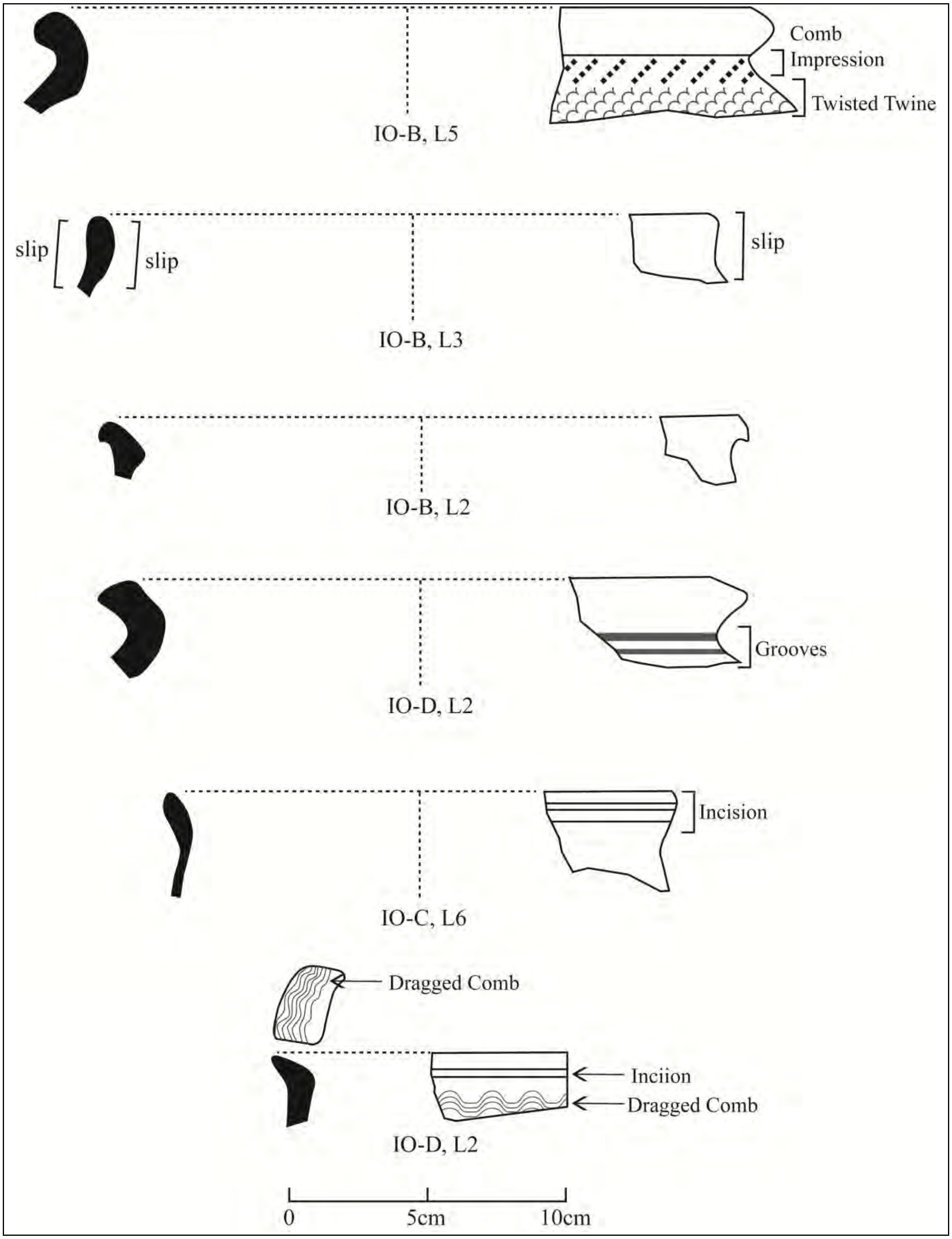


Figure 5.17: Major rim form class: short everted vessels

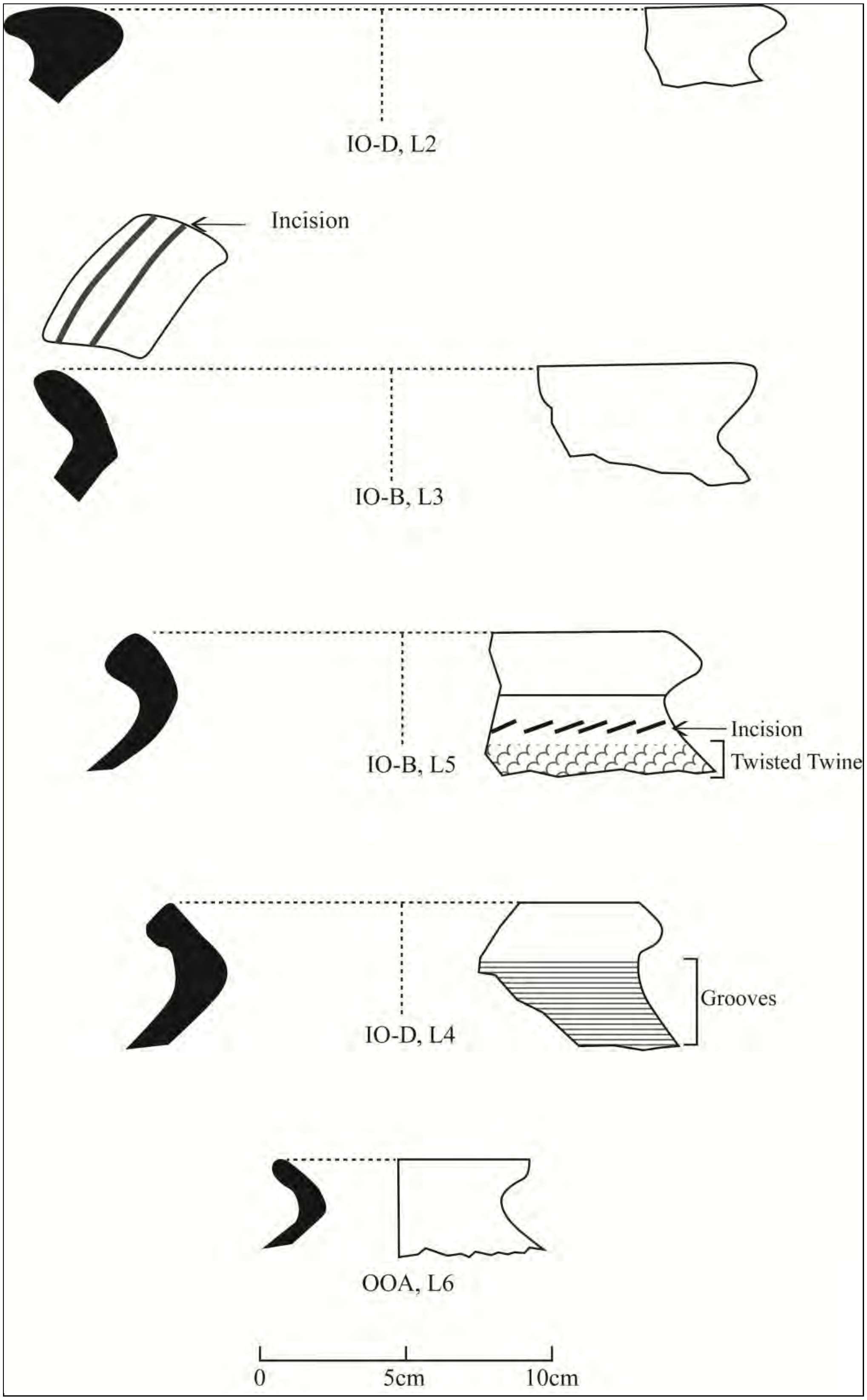


Figure 5.18: Major rim form class: medium everted vessels.

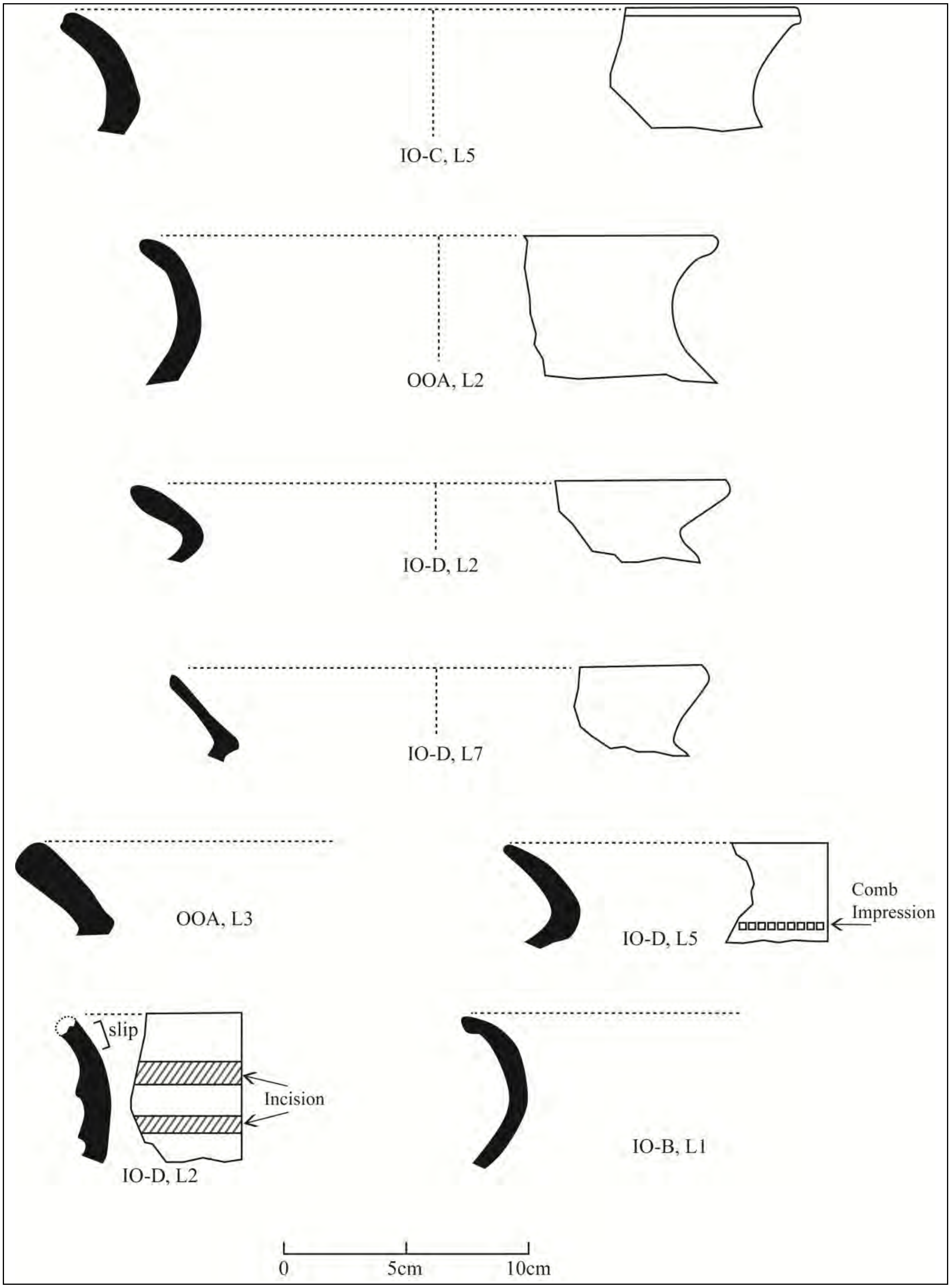


Figure 5.19: Major rim form class: long everted vessels

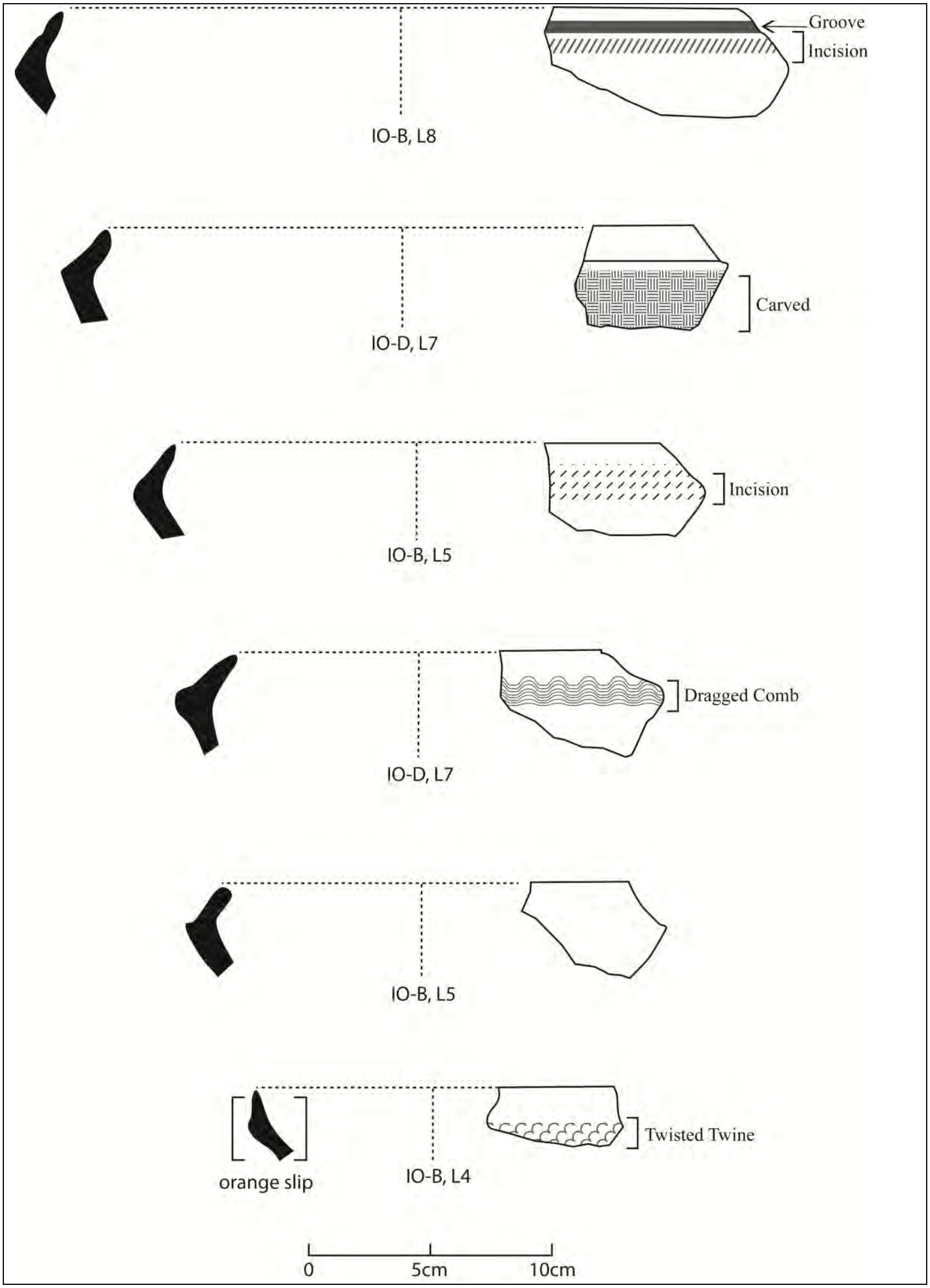


Figure 5.20: Major rim form classes, carinated vessels

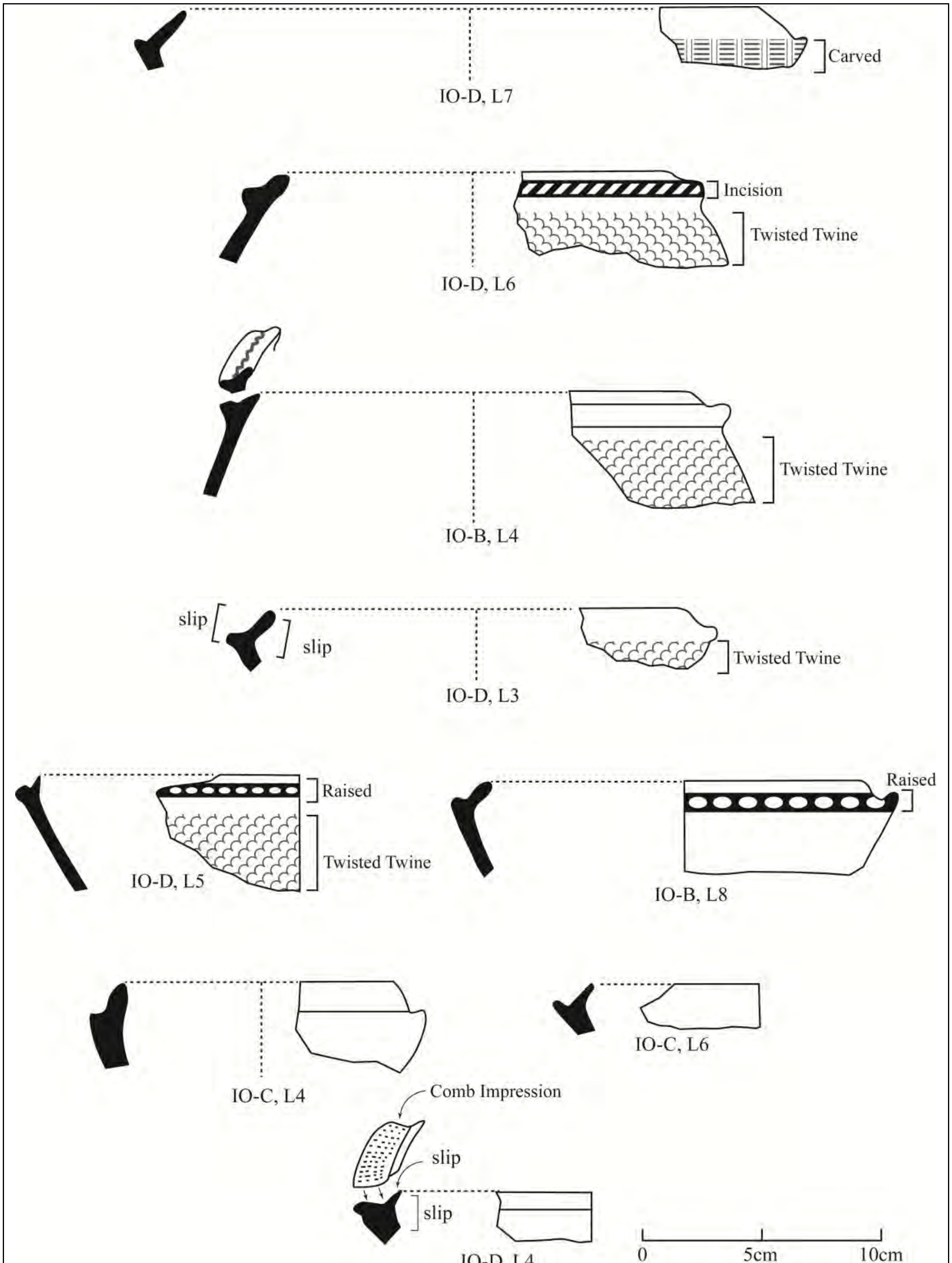


Figure 5.21: Major rim form classes, ledged vessels

Figure 5.22: Potlids handle from the excavations with a possible cylindrical handle.

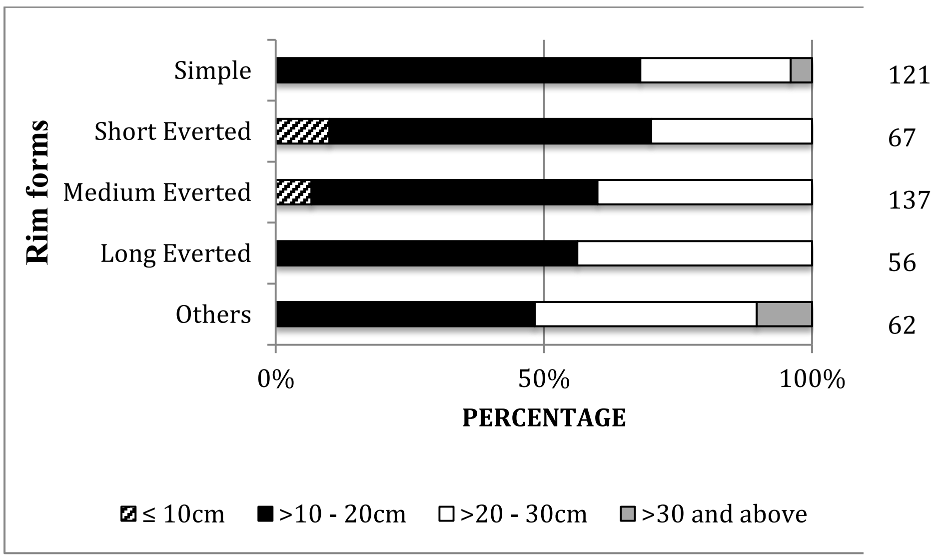


Figure 5.23: Frequency distribution of rim diameter by major rim forms from excavated units IO-B. IO-C, IO-D, and OO-A.

Decoration

Undecorated (plain sherds) and slipped sherds dominate the rim assemblage (Fig. 5.24). The occurrence of slipped rimsherds is consistent among the units varying between 20 and 35%. Slip seems to appear mostly on the lip averaging 75%. Occasionally the entire rim or interior is slipped. In the bodysherd assemblage, plain sherds are much more common; in all units around 80 percent of the body sherds are plain. The remaining 15 - 20% of the bodysherds are either slipped or decorated with single or multiple plastic motifs (Fig. 5. 25).

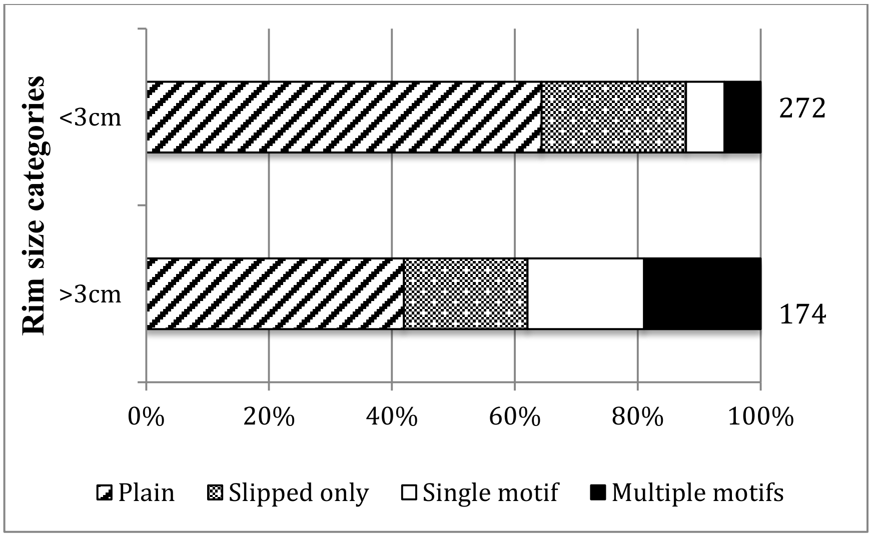


Figure 5.24: Frequency of slipped, plain, and decorated rimsherds from the excavation units by rim size categories. The higher incidence of decoration on larger sherds reflects the increased surface area.

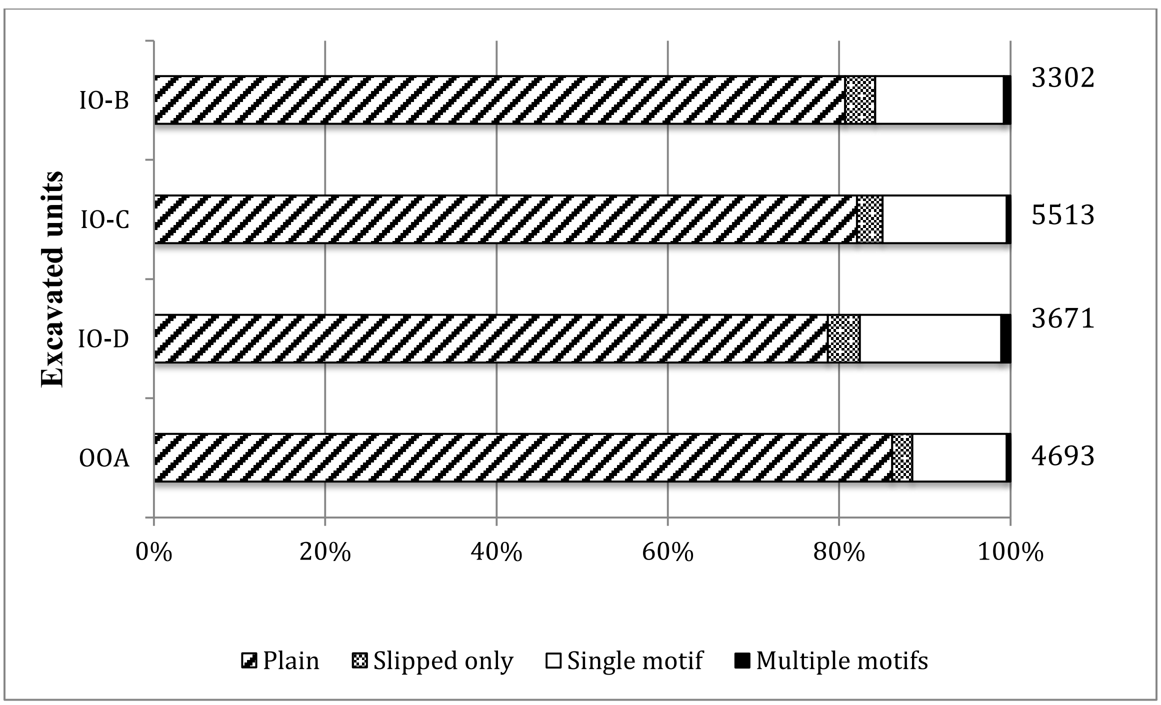


Figure 5.25: Frequency of plain and decorated bodysherds in the excavated units

Among the body sherds decorated with a single motif, carved roulette decoration occurs on 20–35% in all units (Fig. 5.26). Carved motifs 1, 2, and 20 are the most common, accounting for between 65 and 85 percent of the carved roulette motifs (Fig.

5.27). Carved roulette occurs far less frequently on rimsherds (Fig. 5.28). The frequencies of decorative variables in the body sherd assemblages from the different units are quite similar. In the rimsherd assemblages, only OO-A is an outlier, and this may be totally due to sample size.

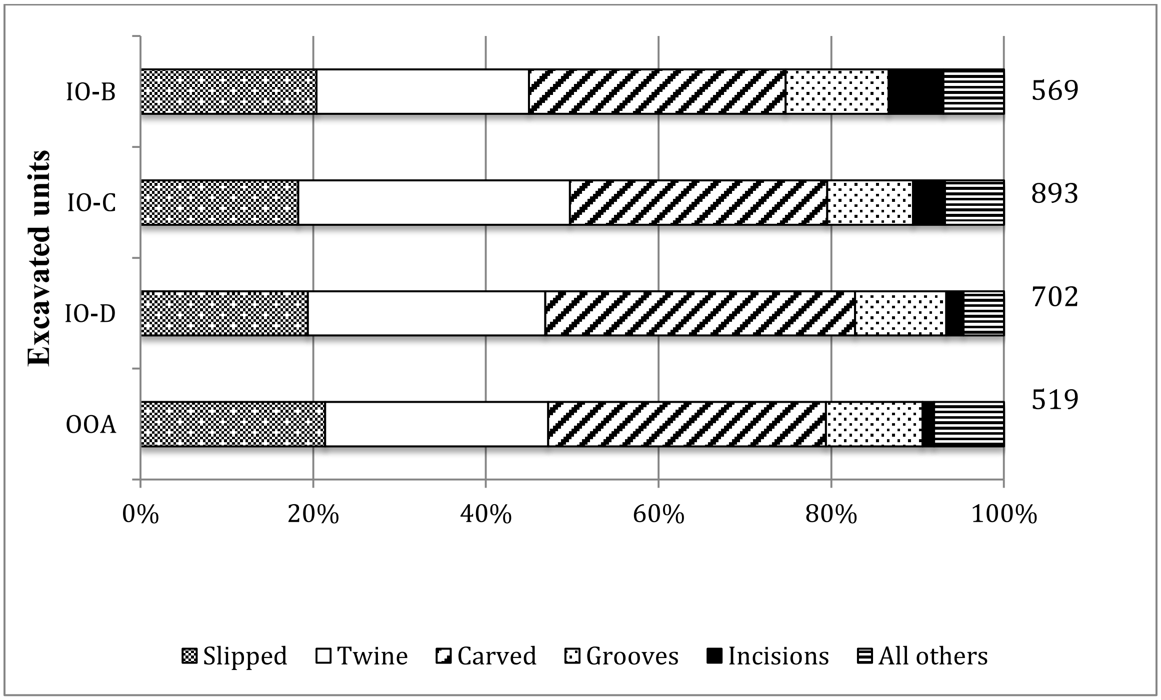


Figure 5. 26: Frequency of slip, twine, carved roulette, incision, and other single decorative motifs on the bodysherds, by excavated units.

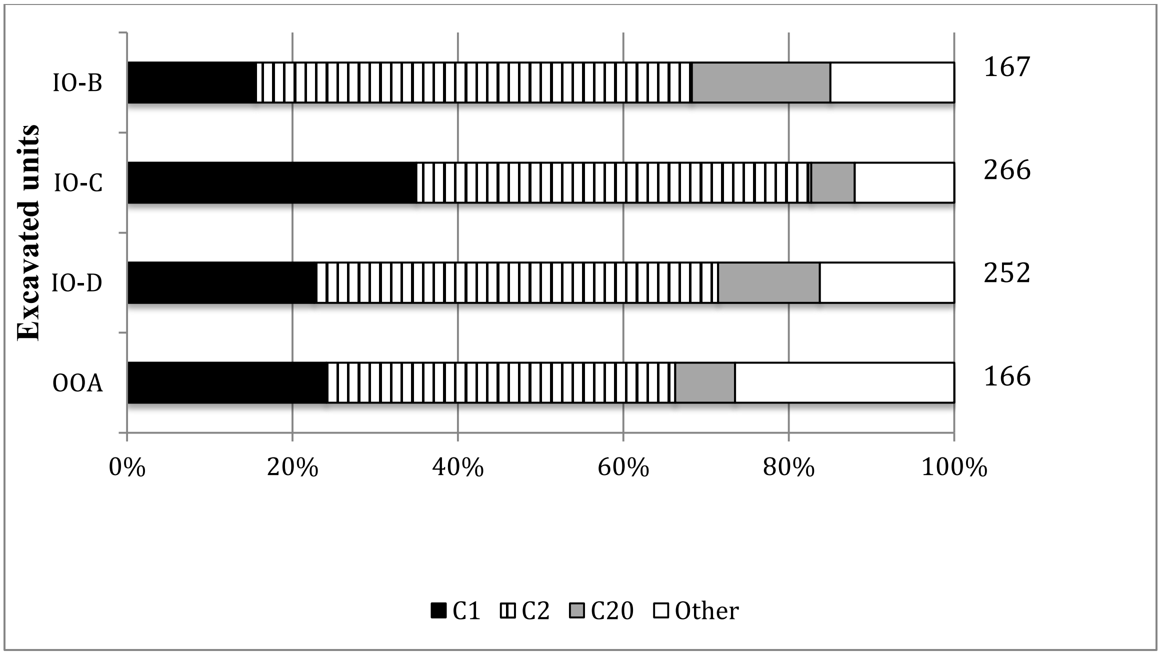


Figure 5. 27: Relative frequencies of specific carved roulette motifs on bodysherds decorated with a single motif.

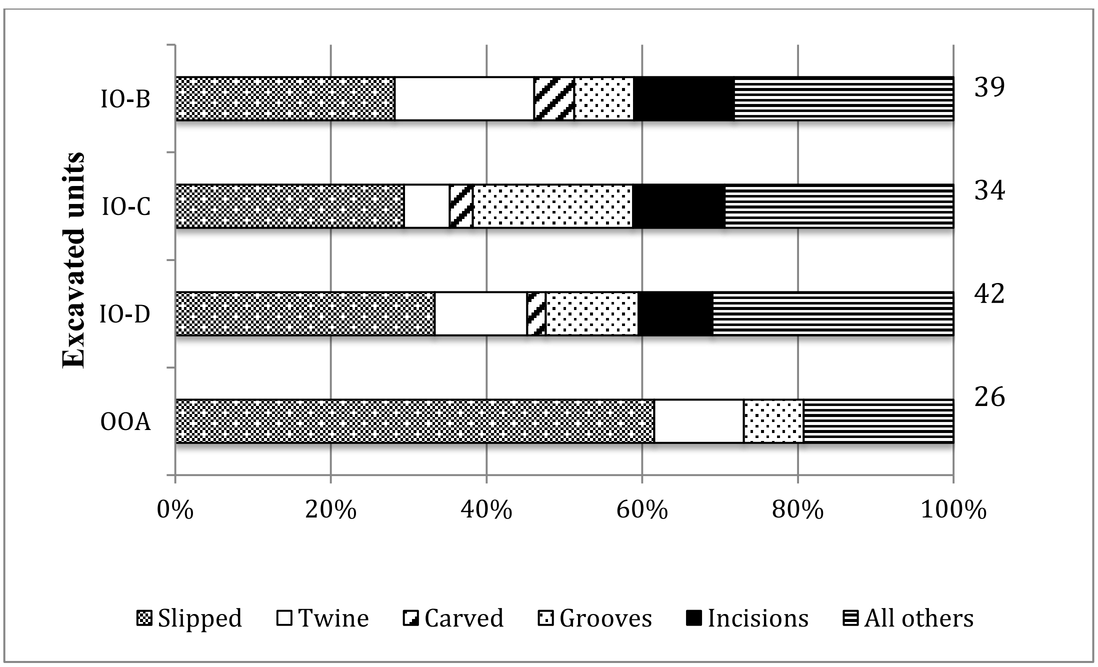


Figure 5. 28: Frequency of slip and decorative motifs on the rimsherds by unit

Other forms of decorative motifs described above occur on the sherds in the assemblage. When combined, single and horizontal grooves are the commonest on both the body and rim sherds. This form of decorative motif mostly occurs accompanying other motifs, especially to border other plastic decorations. However, it is not unusual for the motif to appear as a single or multiple bands on it own. Also, raised decoration is common, which mostly occurs in the form of a rib on the shoulder or body of a vessel. Slip in combination with other decoration also occurs but occasionally. Perforated vessels are very rare; only one sherd was recovered, from level 3 of unit OOA (Fig. 5.8 – right 6).

Decorations appear to concentrate on the shoulder ranging from 30 – 35%. The percentage frequency of decoration concentration on the shoulder is consistent across all the units. Sometime the decoration extends down to the body of the vessel. Similar situation is observable from Garlake's work at Woye Asiri and Obalara (1974, 1977). Occasionally the rim, shoulder, and body are decorated. This is mostly the case when decoration is elaborate or complex. Although we did not recover any complex or near complex vessel to further establish this, examination of the complete vessels illustrated by Garlake (1977: 78-81) support this assertion.

Technical and production variables

To examine paste attributes such as hardness, paste color, degree of oxidation, and non-plastic inclusions, I combined the data recorded for both the small (<3 cm) and larger rimsherds. Paste hardness shows no significant trends: medium paste rigidity has overall highest frequency in almost all the units levels ranging from 30% to 65%. Soft sherds are largely low across all levels and units, except level 2 of units OOA and IO-B. Hard, very well-fired sherds vary between 20% and 50%. This is consistent with the frequency of orange paste (20–80 percent) and fully oxidized sherds lacking a dark, unreduced core (25-100 percent). Although we do not have specific data on the firing form – kiln or open – adopted at Igbo Olokun, the evidence shows that vessels were well-fired at relatively high temperatures within the earthenware range.

Visual observation of fresh breaks of 448 rimsherds – including large and small sherd - with set of hand lenses reveals that crushed quartz, sand, and grog are the non-plastic inclusions (NPI) present. These non-plastic inclusions occur either individually or in combination. Sand as single NPI occurs in approximately 25 percent of the rimsherds. The occurrence of sand may not necessarily indicate use as tempering material. It could have occurred naturally in the potter's clay. The sand, when present, is not enough to give the surface a gritty feel. Thirty-nine percent of the sherds have crushed quartz accompanying either sand or grog. When viewed under hand lenses, the angular nature of the quartz suggests that it was ground or crushed before being added to the potter's clay. Grog is present but rarely as the sole NPI. (Table 5.6).

Rim Forms	Quartz Only	Quartz + Sand	Quartz+ Grog	Sand Only	Sand+ Quartz	Sand+ Grog	Grog Only	Grog+ Quartz	Grog+ Sand
Simple	15	20	27	39	8	3		5	4
Short Everted	11	9	15	17	5	1	2	2	3
Medium Everted	24	20	30	36	7	8	1	6	7
Long Everted	9	10	19	6	4	4		2	2
Thickened	1	2	4	7		1			
Ledged/T-Rim	6	6	7			1			3
Carinated	3	1		5	1	2	5		2
Beaded			2						
Miscellaneous				1	1				
	69	68	104	111	26	20	8	15	21

Table 5.6: Distribution of non-plastic inclusions in rimsherds from the excavated units

Mica is another non-plastic inclusion present in the pottery assemblage. Since mica is most likely a natural component of local clays (Ige, 2010b; Ige *et al*. 2009), its degree of occurrence was observed. Examination of both fresh breaks and surfaces of the sherds shows that mica is heavily present in 35 to 70% of the rimsherds, and absent or nearly so in 5% to 12% of rimsherds, indicating a reliance on local clay sources.

Temporal and spatial patterning

The multivariate approach to pottery assemblage from Igbo Olokun has provided data that facilitate comparison among units and levels at Igbo Olokun, and among different sites within larger Ile-Ife. However, comparison of the rims sherd assemblage is complicated by the low numbers of rims sherds and the likelihood of sample bias. We have seen that everted rims of medium length are the most common rim form in most levels in all Igbo Olokun units, with no discernable patterning over time (Figures 5.11–5.14). Only ledged and carinated rims show a possible increase in relative frequency in the early deposits at the spatially proximate units I-OB, -C, and –D. Unit OO-A does not show this pattern; it produced only one sherd in this category. The overall impression of relative homogeneity in the rim sherd assemblage is reinforced by the data on body sherd decoration. No significant temporal difference can be detected when levels with evidence of recent mixing are compared with early levels across all units (Figure 5. 29). The occurrence of varieties of carved roulette, raised, and geometric decoration suggests that particular attention was given to complex decorations. Based on the ^{14}C dates from these units, the ceramic tradition that dominates in all units and levels can be tentatively dated to between 12th and 15th centuries A.D. If later pottery is present in mixed levels, it is either quite similar to the earlier pottery, or it occurs in very limited numbers. The one clear indicator of later pottery is maize cob roulette, documented from TP1.

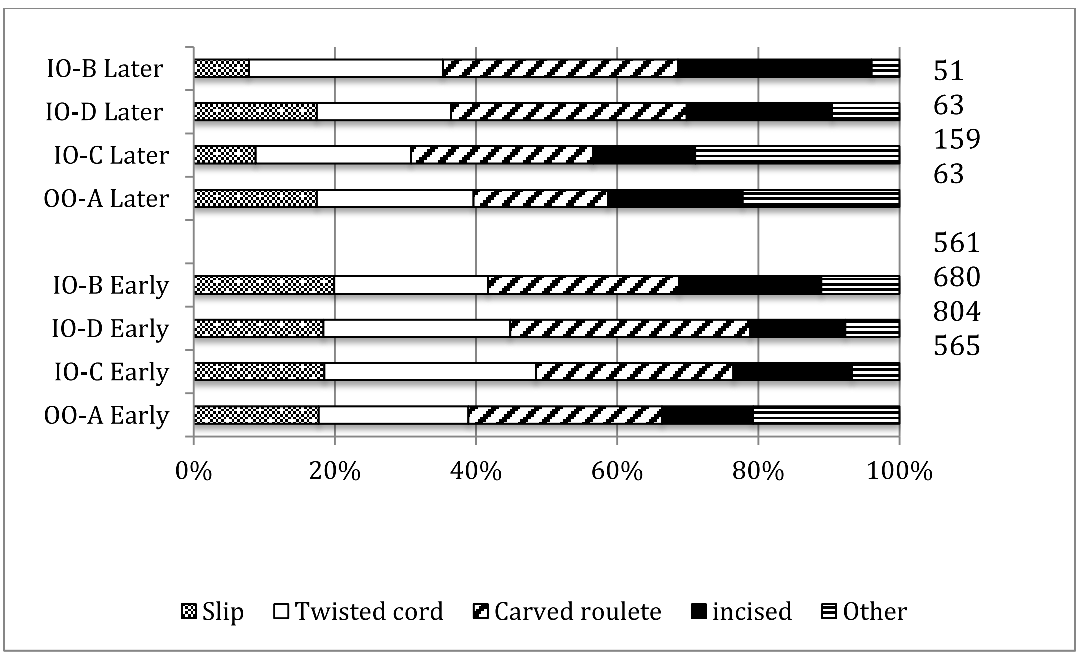


Figure 5.29. Comparison of bodysherd decorations on the later and early levels across all units

Maize did not arrive in West Africa until the 16th century (McCann 2005). The mixing of early material with modern trash was apparent in the upper levels (1-2), and it is not impossible that such mixing would have also impacted the lower levels since deposits extended only to a depth of 55 cm. The ^{14}C date of 1670-1960 A.D. (two sigma with 95% probability) from level 5 (40cm depth) likely reflects this more recent disturbance.

Igbo Olokun and the pottery of greater Ile-Ife

The ^{14}C dates from Garlake's (1974, 1977) Woye Asiri and Obalara sites in Ile-Ife place them within the same time period as the Igbo Olokun units (see Table 4.3). Garlake's detailed pottery data (1974: 137-8, 1977: 78-83) provide the best description available for Ile-Ife pottery dating to the 12^{th}-15^{th} centuries and allow comparison with the Igbo Olokun pottery. There are many similarities in rim form and decoration. The correspondences between my rim form categories and Garlake's vessel types (Figs 5.15 – 21, App. 5.1) are summarized in Table 5.7.

Igbo Olokun	Garlake Types
Simple open	B, J
Simple close	E
Everted medium	A1, A2, C, H
Everted long	A3, A4
Carinated	F
Ledged	D

Table 5.7. Correspondences between rims forms from Igbo Olokun and Garlake's vessel types.

Igbo Olokun yielded only a small sample of rimsherds and no intact vessels, unlike Garlake's excavations, so the comparison will necessarily be a rather general one. In addition, the deposition contexts were quite different: industrial at Igbo Olokun; domestic and ritual at Woye Asire and Obalara's Land. In all cases, everted rims are the most common rim type and ledged and carinated bowls are distinctive components of the assemblage. Figure 5.30 presents Garlake's (1977) main pottery types from Woye Asiri and Obalara sites. The variants within each of these are illustrated in Appendix B.6. Correspondences between Garlake's types and the Igbo Olokun rimsherds is particularly strong with regard to carinated vessels (Garlake's type F variants). However, there are a few differences noticed between the rim forms from Igbo Olokun and Garlake's typologies. First, the simple rim form coded 103 and 104 from Igbo Olokun are absent from Woye Asiri and Obalara (Fig 5. 3). Second, T-rim occurs in units IO-B, & D with a piece from OOA, but is absent at Woye Asiri and Obalara. The absence of T-rims in Garlake's assemblage from these two important sites may suggest that they are mostly associated with industrial activities, although this assertion needs to be further investigated in the future.

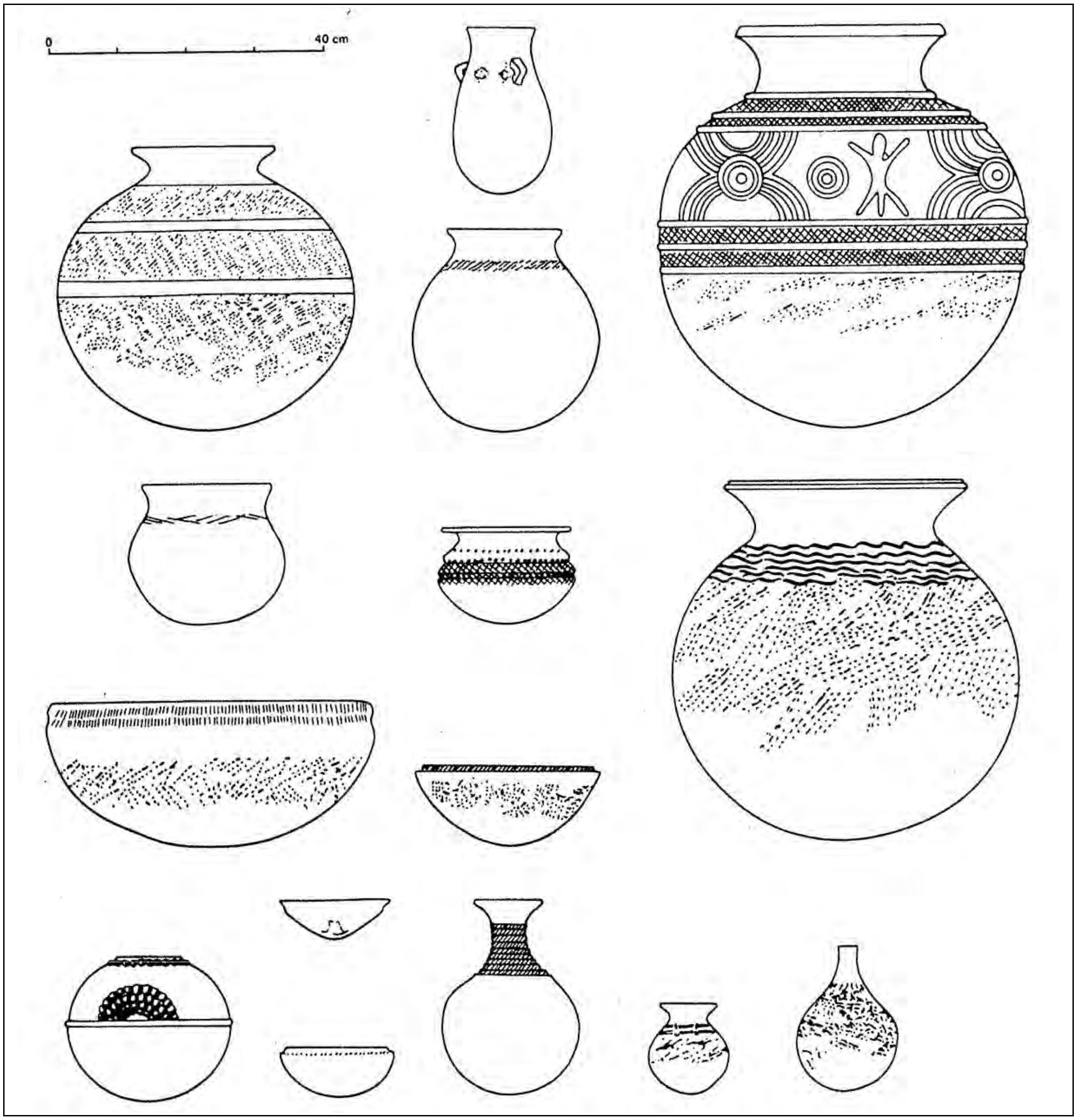


Figure: 5.30: Main pottery types from Woye Asiri, Ile-Ife (Garlake1977: Fig. 13)

Carved roulette, especially ladder patterns, and twine are the most common decoration motifs at Woye Asiri and Obalara, averaging over 70% (Garlake 1977: 85). Similar ladder patterns are classified as C1 through C 11 in Igbo Olokun (see Figure 5.6). Motifs C16 and C20 resembling Garlake's "S" and "U" patterns, respectively, were recognized as important in Igbo Olokun. Garlake does not say anything about their frequency in Woye Asiri and Obalara. Other decorative motifs such as wavy dragged comb, circular stylus, circular and angular punctate, slip, and raised are also present in Woye Asiri and Obalara with some consistency, suggesting similarities with the pottery from Igbo Olokun.

The comparison of the Igbo Olokun pottery assemblages from units IO-B, C, D; OOA, and TP1 with those from Woye Asiri and Obalara sites in Ile-Ife has demonstrated broad similarities that are consistent with a single ceramic tradition. This conclusion is further supported by ^{14}C dates between the twelfth and fifteenth centuries from Igbo Olokun, Woye Asiri and Obalara.

Ile-Ife pottery in broader context

This section considers Ile-Ife pottery in regional perspective. It first discusses the similarities and differences in the pottery from units at Igbo Olokun and Igbo-Rudi, located twenty kilometers away It can be demonstrated that Igbo Rudi constitutes a different, but related assemblage dating to the 16th-17th century. I then compare the Igbo Olokun with that of 1st millennium BC sites in Nigeria, in view of TL/OSL dates from the crucibles that fall in this time period. The purpose is to assess whether there are ceramics present that are consistent with such unexpectedly early dates. If it does, then it will be imperative to unravel the process or agent responsible for the mixing of early and later materials. It is also important because it will help us to start redressing our understanding of the occupation of Igbo Olokun through the studies of its pottery. In view of this, I then discuss the spread of Ile-Ife pottery within the Yoruba and Edo speaking region of Nigeria in the early through mid 2nd millennium A.D.

Although the pottery assemblage from Igbo-Rudi is considerably smaller compared to the totality of the assemblage from Igbo Olokun, we can still make some general statements on the characteristics and the observable differences from the earlier pottery from Igbo Olokun. Igbo-Rudi pottery is characterized by everted rims, and most of the vessels, especially bowls, have carinated shoulders. They have soft fabric, sandy paste, and abundant mica on the surface. Beside twisted cord, incised and punctate decorations are the most common.

The major differences between Igbo-Rudi and Igbo Olokun assemblage are in the vessel forms and decoration. The everted-rim bowls with a low, carinated shoulder from Igbo Rudi (Fig. 5. 31b-d) are not present at Igbo Olokun, nor in classic Ife deposits at Woye Asiri and Obalara. The carved roulette in "ladder patterns" and the rib/raised decoration motifs are completely absent at Igbo-Rudi but are characteristic of classic Ile-Ife pottery. Carved roulettes C1 through C3 are frequent in Igbo Olokun, but absent in Igbo Rudi TP 2. Similarly, the location of the decoration strictly on the neck on the Igbo Rudi pottery contrasts with the earlier Ile-Ife ceramic assemblage.

Comparison of the Igbo-Rudi everted carinated ceramics (Fig. 5.31 c and d) with other supposedly contemporary Yoruba sites is important in order to determine distribution of this vessel form in the 16^{th}–18^{th} centuries. This Igbo-Rudi form bears some resemblance to vessels from the upper Osun region (including Osogbo and Ede-Ile) dating to the 17^{th}–18^{th} centuries (Ogundiran 2009, 2014), and also to vessel type BB3 from the 14^{th}–17^{th} century site of Ila-Yara in central Northern Yorubaland (Usman *et al*. 2005:148-9), where it is uncommon.

In summary, the open carinated bowls from Igbo-Rudi are a novel form not associated with Classic Ife pottery. Also, the zone of comb or incised decoration is new and very "un-Ile-Ife". This vessel forms may represent a distinctive element that distinguishes classic Ile-Ife pottery from the later 17th century assemblage. Identification of this distinction represents the first time 17^{th} century Ife pottery has been described.. Further studies of the pottery from Igbo-Rudi may help evaluate the Ife-Old-Oyo interaction sphere. Finally, the proposed differences between the early (12^{th}–15^{th} century) Ile-Ife ceramics at Igbo Olokun, Woye Asiri, Obalara, and other early sites and the 17^{th}–18^{th} century remain tentative pending recovery and analysis of larger samples that cover longer time periods. However, this study has demonstrated that there might be some change in Ile-Ife pottery through time, contrary to Garlake's (1977: 94) claim that there is little or no change in Ile-Ife pottery through time. Excavation of sites of different time periods would be a strategy to start putting the data together for pottery sequence for Ile-Ife.

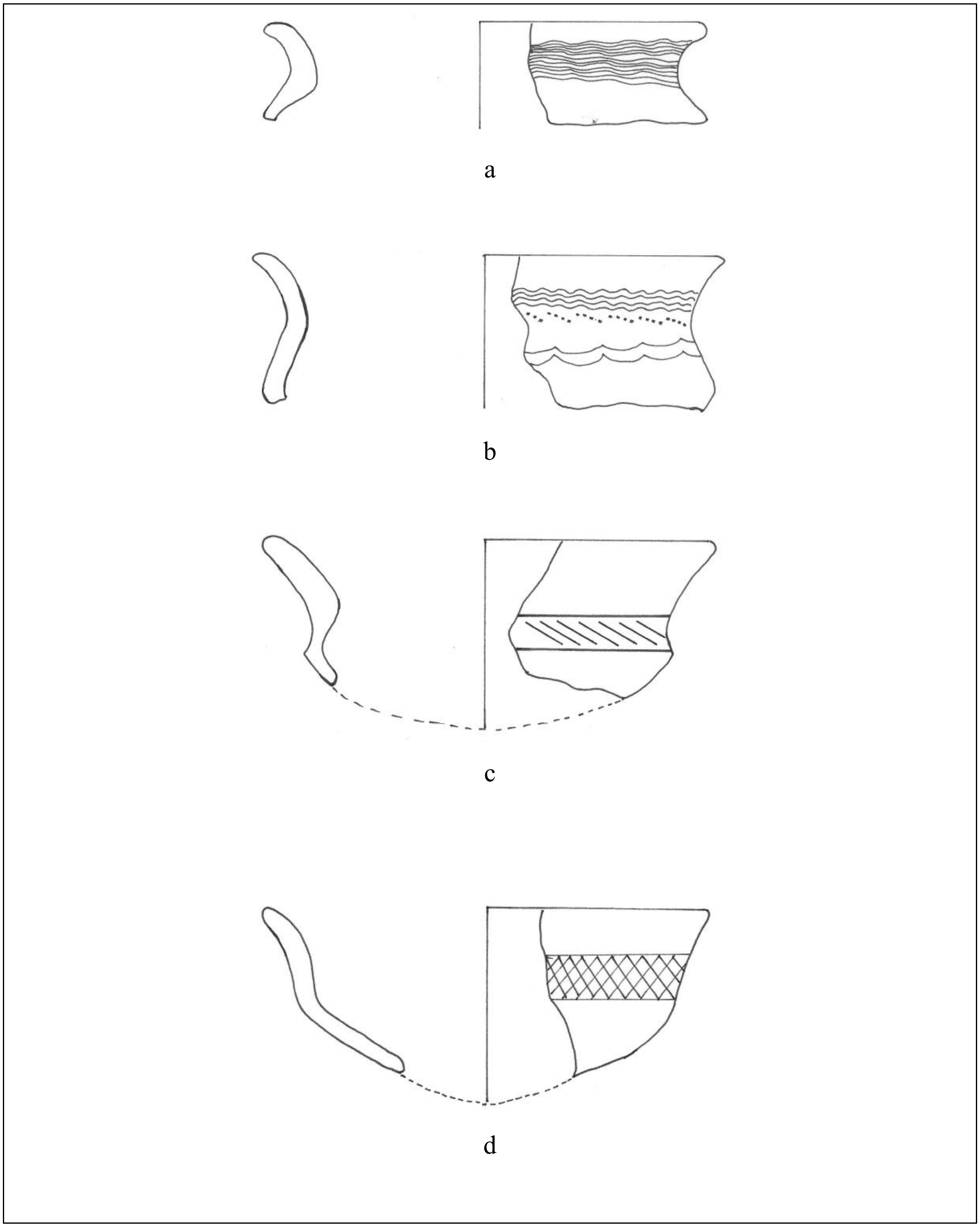


Figure 5.31: Major vessel forms from Igbo-Rudi (IR-TP2), Ile-Ife.

Comparison of Ile-Ife Pottery with 1st millennium B.C sites

The unexpectedly early 1st millennium BC TL/OSL dates on the crucibles obliges us to consider whether any pottery resembling known ceramics of that period is present at Igbo Olokun.To this end, I compare Ile-Ife pottery with other mid/late 2nd and 1st millennium B.C sites in Nigeria. Deposits of this date in Nigeria are usually preceded by older occupation layers belonging to the Late Stone Age (LSA) period (e.g. Hartle 1967, 1980; Chikwendu 1998; Andah & Anozie 1980; Shaw & Daniels 1984).

The upper, pottery-bearing horizon at Iwo Eleru in Ondo State about 80 km southeast of Ile-Ife is an ideal place to start; it is dated to the mid 2nd millennium BC. (Shaw and Daniel 1984). String roulette and incision are the dominant decorative techniques. However, the clustering of comb impression with other lithic material of later LSA period made Shaw and Daniels (1984: 42) conclude that " comb-decorated pottery is genuinely associated with the LSA occupation." While comb-impression is not a common motif in Ile-Ife, the diverse carved roulette motifs of Ife are absent at Iwo Eleru. The wavy comb dragging seems common to both site. Iwo Eleru form 17 appears to have a parallel in Ile-Ife among the carinated and simple open vessels, although there is variation in the decoration on the vessel.

In the Afikpo region of the southeastern Nigeria, the upper horizon of the Ezi-Ukwu Ukpa site dated to the last century of the 1st millennium B.C. is characterized bygray ware which is described as dark, hard-fired with sand or grit temper (Hartle 1980: 196). Common decorations on Afikpo gray ware from Ukpa site include horizontal incisions, cross-hatching, and slashing (Chikwendu 1998: 55). In addition to the paste and firing condition, the red ware of lower horizon at Ukpa site (Andah and Anozie 1980; Hartle 1980: 197-8), which is earlier, is described to have cross-hatching and herringbone decorative motifs (Chikwendu 1998: 55). These decorative attributes of Ukpa pottery also played out at Ugwuagu Rockshelter, another Afikpo site with pottery phase dated to 700-300 B.C. (Chikwendu 1998:51). Although decorated rim sherds were few in number and apparently almost all undecorated (Chikwendu 1998 : 12-13), decorative motifs present (among the bodysherds, presumably) include horizontal incisions, cross-hatching, and slashing (Chikwendu 1998:55).

In further north of Ile-Ife, excavation in Rop site in Jos Plateau has revealed an occupation dated to the last three decades of the 1st millennium B.C. (Fagg 1972), although earlier occupation is believed to have existed at the site (Eyo 1972). Analysis of the pottery from Rop has shown that fiber roulette, incisions, and carved roulette (A. Fagg 1972: 36). While the lager vessels are decorated with fiber roulette, the smaller vessels, mostly bowls, are with carved roulette, especially in A. Fagg's team, chevron design (1972: 36). There seem to be no significant similarity between Rop and Ife pottery. However, the A. Fagg's chevron pattern resembles the zig-zag at Ife. Also the appearance of incision as border for other decoration is common in Ife. This similarity is too minute to suggest any remarkable trend in the pottery tradition at the two sites.

Studies of Nok pottery in north-central Nigeria have allowed characterization of the pottery spanning mid 2nd millennium B.C. through the 1st millennium A.D Through the 1st millennium B.C. decoration of bands of horizontal deep lines filled with diagonal lines, cross-hatching and comb impression, and rocker comb are prominent (Franke 2014a: 171-6, 2014b: 334). Incision and comb dragging are also present. Between 1 and 1500 A.D. many decorations typical of Nok disappeared and were replaced by a new technique – carved wooden roulette (Franke 2014a: 174). The decorated pottery from post-Nok site Janruwa C site had exclusively carved roulette decorations, which appears in several patterns, such as raised dot, chevron, and herringbone. The latter motif also occurs on Ile-Ife pottery. I classify herringbone pattern from Igbo Olokun as C13 carved roulette.

Lastly, Gajiganna pottery in northeastern Nigeria is dated to mid 2nd through 1st millennium B.C. It is characterized by mat impression, varieties of comb impression, geometric bands, and rocker stamp (Wendt 2007: 43-6, 72-6), motifs that are lacking or rare in Ile Ife.. There is thus little to no evidence that would support a date earlier than the first millennium AD for the Igbo Olokun ceramics.

Spread of Ile-Ife pottery in the Yoruba and Edo speaking region

Although there seems to be sparse data for comparison of Ile-Ile pottery with other 1st millennium site across Nigeria, in the 1st through 2nd millennium A.D. Ile-Ife pottery appears to have spread considerably across many polities within the geographical boundary of Nigeria, especially among the Yoruba and Edo speakers (Table 5.8). In Benin, in the south, carved roulette (similar to C7, C13, C16), bosses/cordon, circular stylus, and wavy dragged comb typical of Ile-Ife style appeared in the 12th – 16th century deposit. In addition, of the 25 vessel forms identified by Connah in Benin, five and their variants (form 1, 2, 3, 7, and 8) are similar to Ile-Ife forms, especially the carinated and ledged forms. These similarities in Ile-Ife and Benin pottery attributes have not only point to the spread of Ife pottery but also demonstrate significant interactions between the two urban polities between the 12th and 16th centuries (Eyo 1974a; Connah 1975; Ogundiran 2002a).

There is also wider spread of Ife pottery within the core Yoruba region (Table 5.8). Ogundiran (2000; 2002a) has established that there was significant Ife influence on the potting tradition in central Yorubaland from 12th through 18th century A.D. Cross-hatched/hyphenated incision, slip (mostly on rim and lip), circular stylus, geometric, and relief motifs along with carinated and ledged vessels of Ile-Ife types characterized Iloyi and Okun ceramics (Ogundiran 2000: 377-387). Similarly, Ile-Ife ceramics have been identified in early Osogbo occupation dated to the 17th and 18th century A.D. (Ogundiran 2014). The Ile-Ife pottery tradition occurs both in vessel forms and decoration motifs on pottery from early Osogbo. According to Ogundiran (2014: 13) the “ledged bowl with in-curving rim and horizontal ledge around the bowls greatest circumference; the shouldered bowl, characterized by inverted rim and marked shoulder that is continuous with the hemispherical body of the bowl; and the grooved-rim bowl with inverted rim and hemispherical body” are the major Ile-Ife pottery type present at Osogbo. Ogundiran (2014: 13) has also identified a distinct pottery complex distinctive of early Osogbo, which is completely absent in Ile-Ife. Archaeological investigations in eastern Yorubaland at Igbo Laja site, Owo – a 15th – 18th century ritual site - has shown some similarities in the pottery style with those from Ile-Ife (Eyo 1974; see also Ogundiran 2000 for comparison of Owo, Ife, Ilare, Old-Oyo, and Benin pottery).

Attributes	Ile-Ife Ceramics			Benin Ceramics	Oyo Ceramics	Ilare Ceramics	Oshogbo Ceramics	Owo Ceramics
Decorative Motives	Woye Asiri & Obalara	Igbo Olokun	Igbo-Rudi					
Twisted cord	X	X	X	X	X	X	X	X
Carved roulette#	X	X	X	X				
Boses/cordon	X	X	-	X				X
Relief	X	X	-	X		X		X
Wavy dragged comb	X	X	X	X		X		
Cross hatched/hyphenated incision	X	X	X	X		X		X
Slip (rim/lip)	X	X	-	X		X		X
Circular stylus	X	X	X	X		X		X
Vessel Forms+								
A	X			X	X	X		
A1	X	X			X	X		
A2	X	X				X		
A3	X	X						
A4	X	X		X	X			
B	X	X						
C	X	X						
D	X	X		X		X	X	X
E	X	X						
F	X	X		X		X	X	X
G	X					X		
H	X							
I	X							

Table 5.8: Distribution of Ile-Ife ceramic forms and decorative motifs in other Yoruba and Edo-Speaking sites.

#Carved roulette motifs that Garlake describes as ladder is absent in Igbo-Rudi. Even other carved roulette motives are limited. +The vessel form categories is exclusively based on Garlake's typology.

The northern Yorubaland is the homeland of the Old-Oyo urban complex and several other frontier Igbomina polities with strong cultural affinity with Old-Oyo (Agbaje-Williams 1983, 1987; Usman 2001, 2012; Aleru 2006). However, studies of the Igbomina pottery has revealed the presence of Ile-Ife ceramics in form of carved roulette motifs in the 14th century Igbominaland (Usman 2012). Despite the presence of Ile-Ife pottery decorative attributes in Igbominaland, It seems that Ile-Ife pottery has little to no influence in Old-Oyo. Based on the studies of surface finished and decoration attributes of Ile-Ife and Old-Oyo pottery, Agbaje-Williams (1987) has suggested a dichotomy between the two urban centers in the 12th century A.D. While most of the Old-Oyo pre 15th century ceramics are largely burnished with incised decoration, Ife ceramics are unburnished with carved roulette decoration (Agbaje-William 1987).

Although not much has been done archaeologically in the coastal and western Yoruba regions (see Momin 1989; Allsworth-Jones and Wesler 1998; Ogundele and Odunbaku 2006; Odunbaku 2007; Babalola 2006; Ogundele and Babalola 2007 for limited but ongoing archaeological investigations in the area), research has shown that by the 17th century Ife pottery began to emerge from the archaeological deposit in western Yorubaland. Pottery with red slip in the rim or lip and some carved roulette pattern that characterized Ile-Ife ceramics are present at Orile-Kessi – an early Egba-forest settlement (Odunbaku 2007: 202; Babalola 2006). Although archaeological research is in its nascent stage at Egba Forest kingdoms, the limited archaeological data is supported by oral tradition, which affirms the affinity of the communities with Ile-Ife.

Chapter Six
SMALL FINDS
Introduction

This chapter presents the analysis of other materials recovered from our excavations. These materials are grouped into two: non-pottery ceramic and other artifacts. While the former includes ceramic disc and burnt clay, the latter consists of stone artifacts (querns, mullers, pebbles, flakes, and beads), slag, iron objects, bones, cowries, and snail shell. Modern materials are categorizes as miscellaneous artifacts.

Ceramic

Discs (Figure 6.1). A total of 103 ceramic discs weighing 362g were recovered from excavation, over 50% of them from unit OO-A. The discs were recorded individually, noting variables of provenience, diameter, thickness, weight, and presence or absence of decoration. Observations on the regularity of the shape and mode of production (chipped or ground) were also recorded. Diameters ranged from 1.6–4.8 cm, with most falling in the 2–3 cm, range (Table 6.1). The discs appear to have been fashioned by chipping and/or grinding regular potsherds with a thickness between 0.6 and 1.5 cm. None is perforated.

Similar discs have been reported from elsewhere in Ile-Ife (Fagg and Willet 1962; Garlake 1977); at Woye Asiri, Garlake (1977: 71) describes chipped discs. Ceramic discs with ground edges have been recovered elsewhere in Yorubaland from archaeological context (Ogundiran 2002; Usman 2012). At Igbo Olokun, both chipped (60%) and ground (40%) discs are present. The phenomenon of pottery discs is widespread in West Africa, with use as weights (Garrard 1975) and in flat pavements (McIntosh 1995) noted. . For Ile-Ife Fagg and Willet (1962:359) have identified two types of ceramic discs: large ground disc of about 3.1cm diameters, and thin diameter disc of less than 2.3cm. Considering the association of the discs with pavements, Fagg and Willet (1962: 359) suggest that they were used "as top dressing" for pavement. However, Garlake's recovery of over 12,400 ceramic discs and 1,200 fragments from Woye Asiri has demonstrated that they were used as part of architectural design. He asserts that ceramic discs "were set in the surfaces of mud walls or other vertical features, perhaps columns, as a continuous 'mosaic' finish or in decorative patterns" (Garlake 1977: 71). Ogundiran (2000: 43) found ceramic discs from Iloyi (an early central Yorubaland site) and argues in Garlake's direction that they were part of the "remains of a collapsed structure". Over half of the discs from the Igbo Olokun excavations came from unit OO-A, where the presence of two hearths suggests a domestic, rather than industrial context for the unit, although no structural remains were found. Also ceramic discs from Yorubaland have been suggested as ritual objects common to shrines and temples (Eyo 1974, Ogundiran 2000).

Another possibility worth considering is their use in an industrial context. Although this may be vaguely represented from our excavations, the occurrence of the large category mainly from units IO-B and IO-D may suggest industrial use of the artifact.

Unit	Small 1.6–2.3 m	Medium 2.4–3.5 cm	Large 4.0–4.8 cm	Total
IO-A	2	1		3
IO-B	4	4	4	12
IO-C	6	3	1	10
IO-D	9	7		16
IO-E		3		3
OO-A	28	31		59

Table 6.1: Ceramic disc distribution by size class

Figure 6.1: Ceramic Discs from the Excavations

Burnt Clay

We encountered lumps of burnt clay in every excavation unit, with total weights from each unit ranging from 250 to over 2500 grams (Table 6.2). Various burnt clay lumps occurred in different levels with no obvious clustering. No shape or impression was noticeable to suggest their function and the exact material they would have come from. However, a piece has black carbon on the smooth curve area (Fig. 6.2). They may be remains of furnaces associated with glass or glass bead production at the site. Previous archaeological investigation at Igbo Olokun has recorded the presence of clay furnaces and fragments of tuyere (Eluyemi, 1987: 200). In unit OO-A it is not unlikely that a clay fireplace was constructed. This is evident in the two hearths identified in the unit, previously discussed. Elsewhere in Yorubaland occurrence of burnt clay has been reported in archaeological contexts that suggest domestic (hearth) and/or industrial (Iron smelting furnace) remains (Aleru 2006: 120-121).

Figure 6.2: Burnt clay from unit IO-A (Note the black carbon on the right piece)

Unit	Level	Weight (g)
IO-A	3	15
IO-A	4	242
IO-B	2	10
IO-B	3	15
IO-B	4	462
IO-B	5	203
IO-B	6	470
IO-B	7	100
IO-B	8	292
IO-C	1	5
IO-C	3	35
IO-C	4	44
IO-C	5	231
IO-C	6	61
IO-C	7	173
IO-D	2	158
IO-D	3	283
IO-D	4	366
IO-D	5	723
IO-D	6	1045
IO-D	7 Pit 1	41
IO-D	7 Pit 2	245
IO-E	1	80
IO-E	2	76
IO-E	3	30
OO-A	2	5
OO-A	4	228
OO-A	7	102

Table 6.2: Distribution of excavated burnt clay by unit level and weight

Stone

Beads (Figure 6.3) Two stone beads were recovered from level 3 of unit IO-A and one from level four of unit IO-D. Of the two stone beads from IO-A, one is unfinished and made of quartz material. The quartz bead is of cylinder shape with 9.2mm diameter and 5.7mm length (Fig. 6.3 left). The second stone bead is octagonal and made from carnelian (Fig. 6.3 right). It is 5.9mm in diameter and 3.8mm length. The perforations of these two beads seem to have been created with sand abrasive and a drill bit. The third stone bead from IO-D is different from the other two because it is well-finished and made from orange quartz/carnelian (Fig. 6.3. middle). It is opaque and barrel-shaped. The length is 3.6mm and diameter is 6.1mm. The straight perforation and the regular shape suggest modern fabrication.

Figure 6.3: Stone Beads (Left=Quartz stone bead from IO-A level 4; Middle=Red quartz/Carnalian from IO-D level 3; Right=Carnelian bead from IO-A level 4)

Although no provenience and detail description of was given, Willett (1967: 105) states that red stone beads in a variety of shapes were recovered from excavations in Ile-Ife. Garlake (1974:139) reports the presence of one carnelian bead from his excavation in a context associated with human long bones at Obalara. He also mentions that a carnelian disc was found in excavations at Woye Asiri (Garlake 1977: 89). Radiocarbon dates from Woye Asiri and Obalara placed the context from which the stone beads were recovered to between 12th and 14th centuries. What is unclear however, is the source of the carnelian material. Unlike quartz flakes, no carnelian material was recovered during from our excavations. While the presence of quartz flakes may suggest that stone beads were been worked at the site, the absence of carnelian fragments may indicate that the piece was brought to the site from somewhere else. The closest source area may be the Adrar des Iforas, Mali; carnelian bead production debris was recovered from Gao Saney (Cissé 2011). Other sources include Egypt, but Cumbay, India is considered as the major carnelian production center in the 1st millennium AD (Insoll 1996; Nixon 2008). Thus carnelian beads are suggested to have funneled into West Africa from the center in India through Egypt or from Egypt itself (Insoll 1996; Nixon 2008). Although the rare frequency of carnelian beads at Igbo Olokun and other sites in Ile-Ife may not, for now, suggest great significance in classical Ife, further analysis of the chemical signature of the carnelian will shed more light on the source. A preliminary attempt to chemically differentiate Indian and African sources was not successful, however (Insoll *et al* 2004).

Other stone artifacts. Based on physical inspection of evidence of use and natural marks on the stones, six basic classes were identified: grindstones, mullers, pebbles, slabs/boulders, flakes, and fragments (Table 6.4 & Fig 6.3). Provenience, class and raw material variables were recorded for each of the 69 artifacts (Appendix C.1).

Classes	Material	Characteristics
Grindstones	Granite (Quartzite)	Upper: Smooth/flat surface, rounded edges, Spherical or Cylindrical shape, fist-sized Lower (querns): flat bottomed, Smooth surface with hollow depression
Mullers	Quartzite	Spherical, one or more pecked dimple(s)
Pebbles	Quartzite	Oval, smooth and rounded all over, no evidence of possible utilization
Boulders/slabs	Granite, Quartzite	Mostly flatten, smooth or rough surfaces, no evidence of possible use as grinding stone
Fragments	Granite, Quartzite	Amorphous shape with no evidence to belong to any of the categories listed above
Flakes	Quartz	Amorphous shape, clear, glassy, and probably debitage from stone bead making

Table 6.3: Stone artifacts classes identified from the excavations

Among the classes recognized, grinding stones and stone fragments are the commonest, which appear in at least three to four units. (Table 6.4).

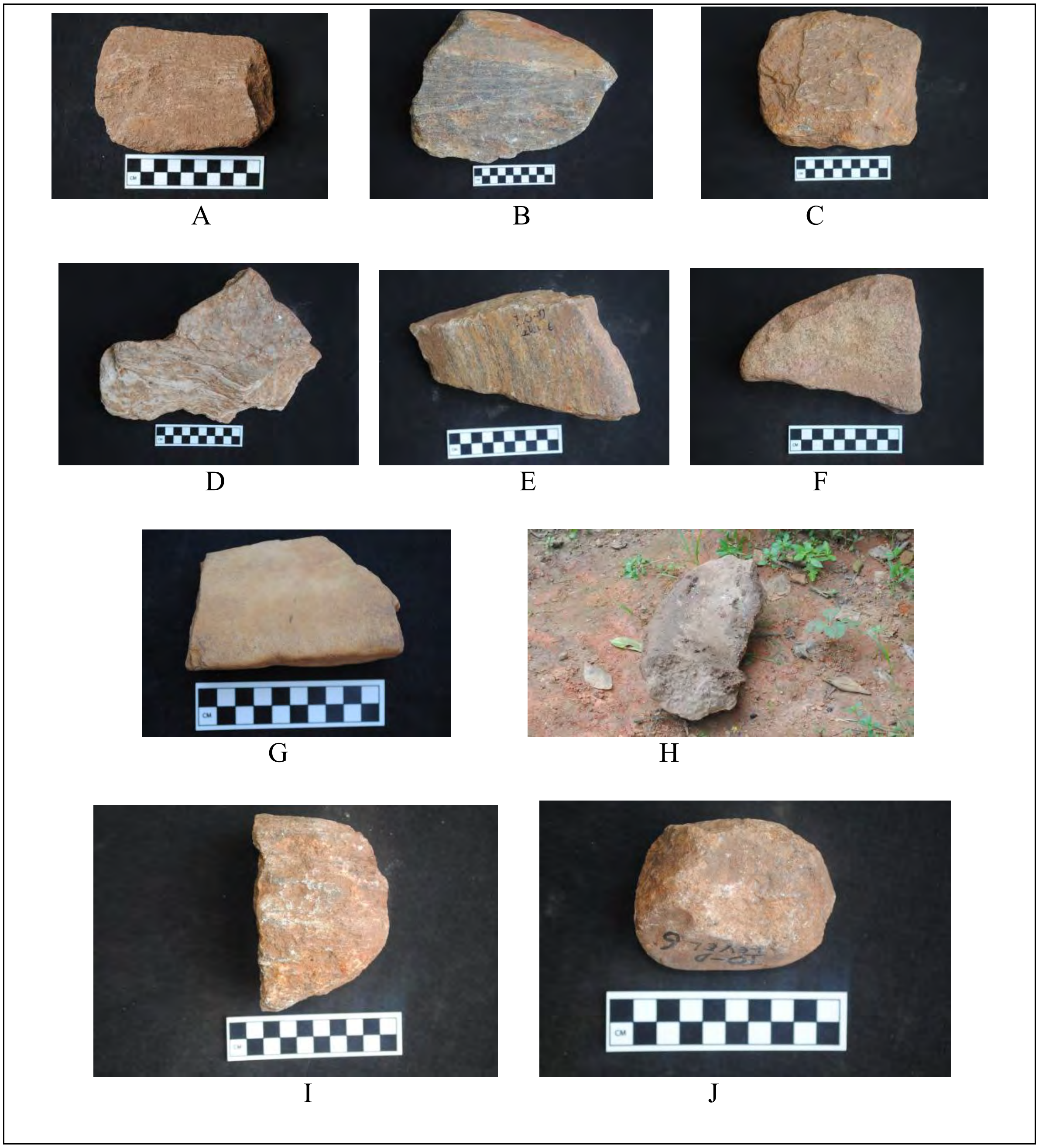


Figure 6.4: Selected Non-bead stone artifacts from Igbo Olokun (A-C - Slabs/Boulders; D-G - Fragments of grinding stones (querns); H – Fragment of grinding stone (quern) showed to us by the indigenes; I – Fragment of upper grinding stone; J – Muller).

The grinding stones include both the upper and the lower (quern), all of which were fragments. The fragmentary nature of the grinding stone, as well as other classes, prevented us from taking their three-dimensional measurements. Thus, no complete grinding stone was found. However, careful examination of their shapes, edges, and surfaces enabled us to differentiate the upper from quern. The complete or almost complete worn-out of the grinding surface of the quern is an important feature that worth noting. Some of the curious indigenes showed us bigger fragments of completely worn-out quern they came across when building their houses (Fig. 6.4H). These grinding stones suggest intensive utilization in crushing of materials for glass bead making. Sourcing of raw material for grinding stone, especially granite, would not have posed a problem for the inhabitant since Ile-Ife and its surroundings are dotted with hills and inselbergs. Most of the hills and inselbergs developed from granite-gneiss and are covered with weathered rock blocks (Jeje 1992:22).

Other non-bead stone artifacts listed above were also present almost across levels in all excavated units, with an exception of IO-E and OO-A where two stone fragments and one muller were recovered respectively (Table 6.4). In addition to the two grinding stone fragments recovered from pit 2 of units IO-B and D, one slab/boulder and pieces of stone fragments came from the pit. Like other slabs/boulders, the one from pit 2 also have red-orangish coloration around the surfaces (Fig. 6.4). The coloration looks more natural, which could have resulted from decay process, than cultural. Thus, no cultural interpretation can be inferred from the boulders particularly in relation to glass bead production. However, elsewhere in Ile-Ife and other places in Yorubaland (e.g. Iloyi) muller and slabs have been recovered from archaeological contexts that suggest both domestic and ritual use (Garlake 1974:123, 140, 1977:90; Ogundiran 2002: 116).

Units	Grind stones	Mullers	Pebbles	Slabs/ Boulders	Flakes	Fragments	Total
IO-A	1				9		10
IO-B	3		4	1		18	26
IO-C	1			2	3	5	11
IO-D	4	1	1	1	1	11	19
IO-E						2	2
OO-A		1					1
Total	9	2	5	4	13	36	69

Table 6.4: Counts of stone artifacts classes by units

Iron and Slag

Slag (Figure 6.5). A single piece of slag was recovered from level 2 of unit IO-E weighing 124g No slag was recovered from any of the other units. Although the presence of slag in an archaeological excavation may suggest iron smelting or smiting at or near the site, the low occurrence of the slag coupled with the shallow/modern nature of the unit make this interpretation challenging. However, Eluyemi (1987: 200) has reported the occurrence of slag in association with tuyere fragments from Igbo Olokun, and concluded bead making and Iron smelting were contemporaneous at the site during Ile-Ife classical era. Since various production debris at Igbo Olokun can mimic iron slag, it remains to be seen whether further investigations will show slag in significant quantities at the site It would be interested to chemically analyze the material identified as slag in order to determine if it smelting or smithing slag, as well as investigate its possible source.

A corroded iron object weighing 10.7g was recovered from level 7 of unit IO-D (Fig. 6.6). The length of the iron is 5 cm with almost 1cm in diameter on the shaft. Because of the degree of corrosion, the actual shape of the shaft could not be determined. Since the iron object was isolated among the finds, it is difficult to make definite interpretation. However, It is not impossible that it was part of the tools used in making glass beads. Willet (1967: 24, 1977: 22) has suggested a situation whereby iron points were used to create holes in melted glass in classic Ile-Ife. Although we could not determine if the iron object had a pointed end or not, it could be fragments of the apparatus used in industrial production. On the other hand, it is also likely that the iron object belong to the later period as it came from pit two, which has a later radiocarbon date.

Figure 6.5: Slag from Igbo Olokun, unit IO-E

Figure 6.6: Iron object from Igbo Olokun, unit IO-D

Organics

Organic materials recovered from the excavations include animal bones, cowrie shell, and snail shells. The animal bones recovered are small in quantity and mostly fragmented. The bones together weighed 48.5 grams. Abigail Stone of the Washington University provided expert observation on the bones, and identified the few teeth, splinters of long bones, and an incredibly tiny un-fused femur. This examination showed that most, if not all, of the bones would have come from sheep/ goat. Abigail Stone (2013 per. comm.) suggested the tiny femur belong to new born or unborn lamb or kid. This came from the top level of unit B and may have been very recently deposited, as bone preserves rather poorly in the soils at Ile-Ife.

One cowrie each was recovered from level 8 of TP 2 and level 1 of unit IO-B (Fig. 6. 7). The cowrie from TP 2 is 15mm in length with angular curvature. The second is about 22mm in length and smooth in shape. They are both cut or perforated to make a hole through them. The characteristics of these cowries suggest that the former is *Cypraea moneta* species, which were exported in large quantities from the Maldive Island in the Indian Ocean (Hogendorn and Gemery 1988). The latter is *Cypraea annulus* and its subspecies are found in Indian Ocean, east coast of South Africa, the coast of Kenyan and Tanzania, and well as the coast of Madagascar and Mozambique among other places, most of which in pre-colonial West Africa are suggested to have originated from from Zanzibar Island, East Africa (Johnson 1970; Hogendorn and Gemery 1988).

Figure 6. 7: Cowrie shells from the excavated units (TP 2 = Right; IO-B = Left)

Cowries are highly significant in African archaeology. They may provide a chronological indicator (York, 1972), evidence of trade (Mauny 1961; Hogendorn and Johnson 1986), and apparatus for ritual (e.g. Eluyemi, 1977). Historical documents and early European account reveal that cowries were used in West African as currency in economic transactions and ornaments between the 11th and 15th century (Levtzion and Hopkins 1981; Hogentorn and Johnson 1986). Cowries have also been reported from a pre-15th century archaeological context in Benin, southern Nigeria (Connah 1975). Despite the occurrence of cowries in West Africa prior to the 15th century AD, cowries did not become ubiquitous materials in the sub-region until the 16th century. Between the 16th and 19th centuries there were mass importations of cowries into West Africa through the Atlantic route (Hogentorn and Johnson 1986; Gregory 1996; Ogundiran 2002). The importation led to significant circulation and monetization of cowries, as it became a major exchange for slaves. In fact, Saul (2004) has demonstrated the use of cowries in the Volta region of West African during the colonial era, and efforts of the colonial administration to replace the shell money with the French franc witnessed a strong opposition by the indigenes. The proliferation of cowries between the late 16th and 19th centuries in the archaeological record of the Yoruba and the Edo speaking region has been argued to usher in a significant cultural translation in the social, political, and economic life of its inhabitants that cuts across the sacred and the mundane spheres (Ogundiran 2002: 437-455). No doubt that cowrie shells have been recovered from different context in archaeological sites in Yorubaland with interpretations that suggest any of the above views on interpreting cowries in archaeological record (e.g. Eluyemi 1977; Ogundiran, 2001; Aleru, 2006). However, the lone cowrie from our excavated unit IO-B and its occurrence in the upper level is not sufficient to make any claim on what it may represent. The cowrie from level 8 of TP 2 is overlain by the horizon radiocarbon dated to the 17th century.

Several fragments of snail shell weighing 11.8 grams were recovered from our excavations. Close examination of the shells suggests that they do not belong to the giant African snail *Achatina achatina* spices. Rather they look more like *Limicolaria* species. Although *limicolaria* are edible, they also can occur naturally in an archaeological deposit (Aleru, 2006:119). It is hard to come to the conclusion whether those from our excavations were part of the culinary pattern or occurred naturally. This inconclusiveness is in part due to the fragmentary nature of the shell. In addition, no associated materials or feature could corroborate firm claim.

Miscellaneous finds

The upper strata of all the excavation units, especially level 1 and 2, yield a variety of modern materials such as chinaware, plastic, nails, iron objects, stainless steel objects, necklace, rubber, and broken bottle glass. The occurrence of these materials is not surprising because trash dump is close to all the sites. In addition, as mentioned in the previous chapter, the location of the site in the center of the city makes them venerable to such dumping. However, the modern artifacts did not go beyond levels two in all the units.

Chapter Seven
GLASS BEADS

Introduction

This chapter describes the major characteristics of the glass beads recovered from our 2011-2012 Igbo Olokun excavations and presents results of laser-ablation inductively-coupled plasma mass spectrometry (LA-ICP-MS) analysis conducted by Dr. Laure Dussubieux (The Field Museum, Chicago) on a sample of 49 beads. Most of the glass beads recovered are in good condition, allowing detailed studies of the assemblage. I use the results of the compositional analysis to consider the question of production source areas and to compare Ile-Ife glass beads with glass beads from other archaeological sites in West Africa. Finally, I discuss the regional and trans-regional movements and/or distributions of Ile-Ife glass beads among other early West African communities during the 2nd millennium A.D.

Methods of recovery and recording

All excavated dirt was screened through 1mm mesh screen, resulting in the recovery of masses of small beads that would otherwise have been easily missed. In all, almost 13,000 glass beads were recovered from the Igbo Olokun excavations in 2011/2012, an unprecedented number from relatively modest-sized units. Prior archaeological work at Igbo Olokun did not employ screening with small mesh, raising the possibility that reported numbers do not fully represent the glass beads present, especially those in the smallest size category. All the recovered glass beads were placed in plastic bags labeled with the provenience information, including site name, unit name, excavation level, excavation date, and excavator(s) initials. While beads were recovered from all six of the 2011/2012 units, most came from units IO-A through D. The glass bead assemblage from unit IO-A was deposited at the Ile-Ife Museum and is not included in the analysis presented here. Additionally, the glass beads from our 2010 test are not included as they are described elsewhere (Babalola 2011). Associated with the glass beads are manufacturing debris of various kinds including unfinished beads, glass canes, cullet, and fused beads among others. The manufacturing debris is discussed separately in Chapter 8.

All glass beads were washed in water with a soft brush, sun-dried, and re-bagged. Washed and dried glass beads from the same level were then separated into three broad categories: complete beads (for which a diameter could be determined), bead fragments, and manufacturing debris. Manufacturing debris included all others such as glass canes, deformed beads, cullet, droplets, and bead clumps (these categories are described in Chapter 8). We counted and weighed complete beads; the other two categories were only weighed.

I recorded multiple variables for each bead, using the system initially developed by Marilee Wood (2000, 2005, 2011) for glass beads in southern Africa. This represents a considerable expansion over earlier descriptions of Igbo Olokun beads by Eluyemi (1987: 203-213), who considered only three variables: shape, color, and diaphaneity. The most detailed and systematic work on West African glass beads to date is by DeCorse *et al*. (2003), but it concerns primarily post-15th century glass beads produced in Europe and is "not orientated toward large collections of small monochrome drawn beads" (Wood 2011: 68), which dominate the early West African bead assemblages, including those at Ile-Ife. The variables I recorded are: color, shape, size, end treatment, patination, and manufacturing technique. Because of the large number of beads (c. 13,000) and the dominance of certain colors and shapes, I recorded the beads by color categories (blue, green, yellow, red, black/gray, and clear, each of which was then subdivided into shape groups, manufacturing techniques, end treatment, and size. Patinated beads as well as the overall surface condition were noted in the comments column of the spreadsheet. Each of the variables is described below.

Color: Five major color categories were recognized in the assemblage, with the range of each color determined by use of a Munsell Color Chart (Table 7.1). Although beads in these color categories were monochrome, the red and the black/gray need further explanation. In the case of the red color, there were two classes: monochrome red and those with clear core and red coating on the outside. Most of the red in the assemblage were in the latter categories, which I recorded as "red/clear." Determining the black/gray on the other hand posed a great challenge because most of the beads of this color were highly opaque. Occasionally, when looked at under reflected light some of the so-called black appeared vaguely as dark gray or green, although in most cases, it is difficult to say categorically to which category they belong. Because of this difficulty, I grouped glass beads of this characteristic into a large color category "black/gray/dark green".

Visual color	Munsell values
Red	10R 2/2; 7.5R 2/2, 2/4, 6/2, 4/8, 3/6
Yellow	2.5Y 6/6, 7/8
Green	2.5 BG 6/2; 7.5GY 3/2, 5/2
Blue	2.5PB 3/6, 5/6; 5PB 3/8; 10B 4/4
Black/gray/dark green	N1.25; N1.5

Table 7.1: Color categories and Munsell color values for Ile-Ife glass beads

In addition to the monochrome categories, there were some striped glass beads in the assemblage. The striped motifs were predominantly parallel vertical stripes, although a few were spiral. Colors included: red on clear; red and white on clear; red and white on blue; white on blue; white and black on blue; red on blue; red, yellow, and black on blue; white on black; white and black on red; black on red; and red on yellow with clear core (Fig. 7.1).

Dichroism: This is a property of glass that appears to be one color in reflected light and another in transmitted light. A small portion of the blue beads appear greenish-yellow in transmitted light (Fig. 7.1). Blue dichroic beads have a characteristically dull surface with a slightly gray cast, as has been noted in previous studies of Ife beads (Davison *et al* 1971; Davison 1972). The number of dichroic blue beads was recorded for each shape category and excavation context (Table 7.2).

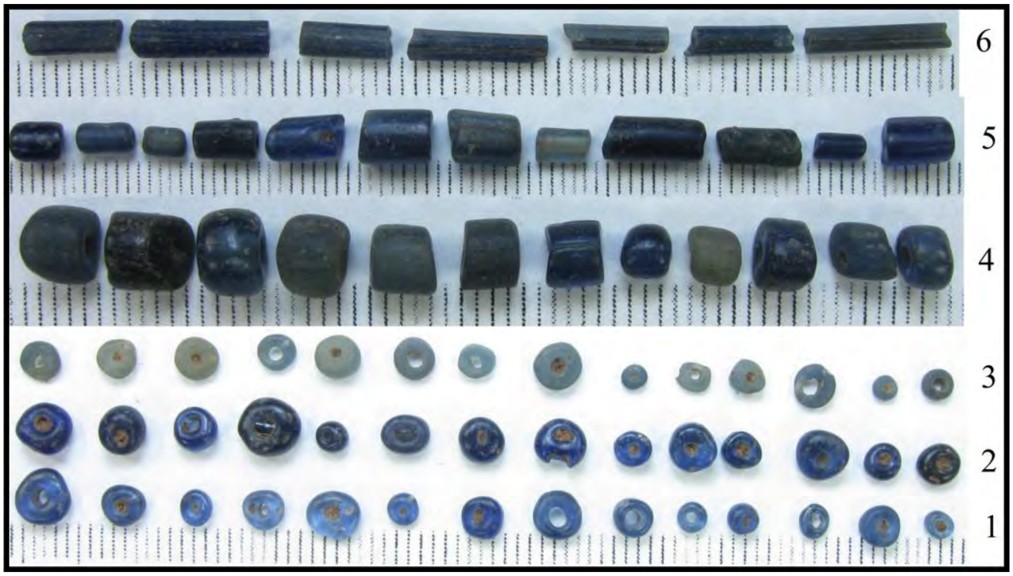


Figure 7.1. Igbo- Olokun glass beads by color and shape (1, 2, & 3 = oblates [3 = all dichroic]; 4 = cylindrical; 5 = partially or well treated tubular; 6 = untreated tubular).

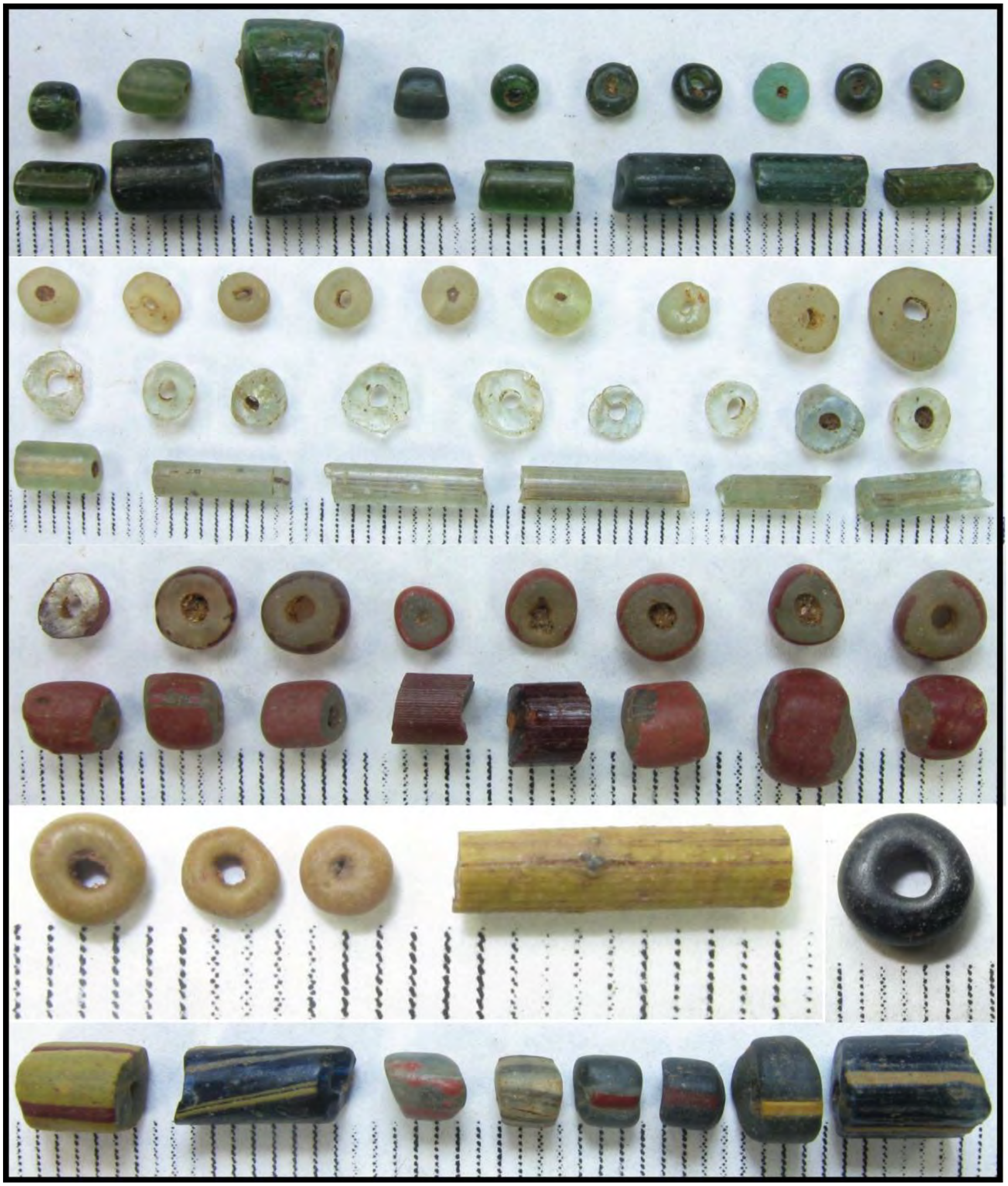


Figure 7.1 (Cont.). Igbo- Olokun glass beads by color and shape

Unit	Level	Cylinder	Tubular	Oblate	Total
IO-B	1	6	1	0	7
IO-B	2	0	1	0	1
IO-B	3	0	0	0	0
IO-B	4	11	11	0	22
IO-B	5	6	0	1	7
IO-B	6	0	0	0	0
IO-B	7	2	0	0	2
IO-C	1	5	2	0	7
IO-C	2	11	5	2	18
IO-C	3	6	1	1	8
IO-C	4	18	4	1	23
IO-C	5	12	18	3	33
IO-C	6	15	12	2	29
IO-D	1	1	2	0	3
IO-D	2	3	2	2	7
IO-D	3	8	2	2	12
IO-D	4	9	2	2	13
IO-D	5	4	5	3	12
IO-D	6	7	5	2	14
IO-D	7	3	0	1	4
Total		**127**	**73**	**22**	**222**

Table 7. 2. Distribution of dichroic beads from Igbo Olokun excavations, by shape.

Shape: Three shape categories are present: tube, cylinder, and oblate (following Wood 2005:31). Figure 7.2 illustrates and describes these. Tube: ends are usually either slightly rounded or entirely untreated (snapped). Cylinder: usually reheated, rounding the ends. Oblate: reheated, resulting in a "smoothly rounded profile" (Wood 2005: 31). Over-heated oblates have a wider perforation with a doughnut shape.

Tubular: length ≥ 2x diameter


Cylindrical: length >1x<2x diameter

Oblate = length ≤ diameter

Figure 7.2. Definition of shape categories

Size: Because of the large numbers of beads, individual bead diameters were not measured. Instead, two size categories were established based on visual estimation of diameter. Most of the glass beads in the assemblages are ≤5 mm diameter, with a few larger than 5 mm. The larger beads, easily recognized, form size category 1. All smaller beads were recorded as class 2. While length of the cylinders and oblates varies between 1 and 6 mm, tubes range from 3 to 11 mm. Rarely, there are tubes with lengths over 11 mm.

Perforation: the perforation is parallel to the length of and striation on the beads. Examination of the perforation shows no drill marks. Furthermore, the very fine nature of the perforation in many of the tubes and minute oblates rules out the drilling technique. Rather it shows that the perforation would have been "made by creating a hollow in a gather of molten glass either through blowing or perforating with a metal tool" (Wood 2005: 28).

End treatment: This describes the condition of the ends of a bead. Two categories were recognized: rounded and snapped. Rounded ends show that a bead was finished and treated by reheating or grinding. Different degrees of "roundness" may be noted (Table 7.3). Snapped ends on the other hand signify unfinished or untreated beads, with sharp ends.. Separating untreated from unfinished is not possible because sometimes bead makers deliberately leave beads ends untreated. As a result the term untreated is used throughout this analysis except otherwise stated.

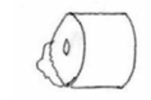
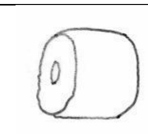
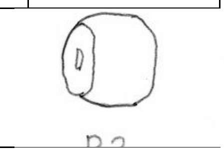
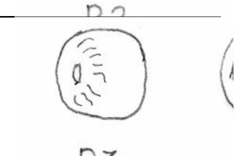
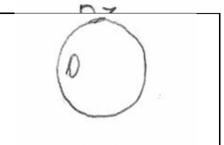
Roundness	Description	Resultant bead shape	Illustration
R0	Untreated	Chopped tubes (snapped)	
R1	Slightly reheated	Tubes	
R2	Reheated to point that edges are beveled	Tube to cylinders	
R3	Reheated enough to round bead’s ends and part of body	Cylinders	
R4*	Reheated to point where profile is totally rounded	Oblates or spheres	

Table 7.3. Stages in end treatment of a bead “roundness factor” (after Francis 2002: 25-26 and Wood 2005: 38). * was added to Francis’ stages by Wood (2005).

Patination: Patination refers to surface corrosion, a complex process affected by a large number of variables (Arman and Kuban 1992; Dal Bianco *et al* 2005; McLoughlin *et al* 2006; Dussubieux *et al* 2009). Among these variables is the quality and composition of the glass. The amount and type of flux, in particular the lime and alumina content, influences the degree of resistance. For example, glasses with elevated alumina (Al_2O_3) have more resistivity to corrosion/patination than those with low alumina (Dussubieux *et al* 2009). Over 90% of the glass beads in our assemblage were well preserved without any form of patination. The few patinated (approximately 1.1% of the whole assemblage) glass beads had a white coating on their entire surface. At the initial stage of the analysis these were mistaken to be shell beads. As the recording proceeded, I came across a clump of patinated beads, indicating that they were glass rather than shell. When dipped in water, some of the patinated beads did not reveal their original color, which showed that the patination was really deep. Beads with this condition were counted, weighed, and noted in the comment column of the spreadsheet.

Other surface characteristics: In addition to noting surface corrosion, we note the presence or absence of striations and bubbles, and the degree of smoothness. There are fine parallel striations on the surface of many of the beads, especially among tubes and glass canes. Many of the cylinders and oblate have a smooth surface, which could have resulted from deliberate smoothing or reheating process. There are few bubbles in some of the beads.

Manufacturing technique: All the beads from our excavations are drawn from a tube. This was recognized by the arrangement of air bubbles in the glass paste, which all aligned parallel to the perforations. Also, some forms of manufacturing debris that characterize the drawn technique were recovered (see Chapter 8).

The Igbo Olokun glass bead assemblage: Description and Overview

The recorded database includes 10,867 beads out of the 12,877 beads recovered from excavation. Beads excluded from the analysis include all patinated beads and beads from unit IO-A, which were deposited at the Ile-Ife Museum. Figure 7.3 shows the frequency distribution of the glass beads across all the units by color with the exception of unit IO-A.. The largest number of glass beads came from Unit C with highest density of 3193 per m^3 in level four. Level three of Unit IO-B/D follows in density of 2878 per m^3 .

Igbo Olokun glass beads occur in different colors and transparencies (diaphaneity). Monochrome, transparent and translucent blue is the dominant color category in all units; polychrome striped and yellow are the least common categories (Fig. 7.3). Only a few beads in the assemblage are opaque, usually occurring in the infrequent yellow, dark red, and dark gray/black colors. Entirely red glass beads rarely occur; rather red appears as coating on the outside of colorless glass beads. Striped beads likewise have a clear, or a blue core, with a range of colored stripes on the exterior. No eye or chevron beads were recovered from Igbo Olokun.

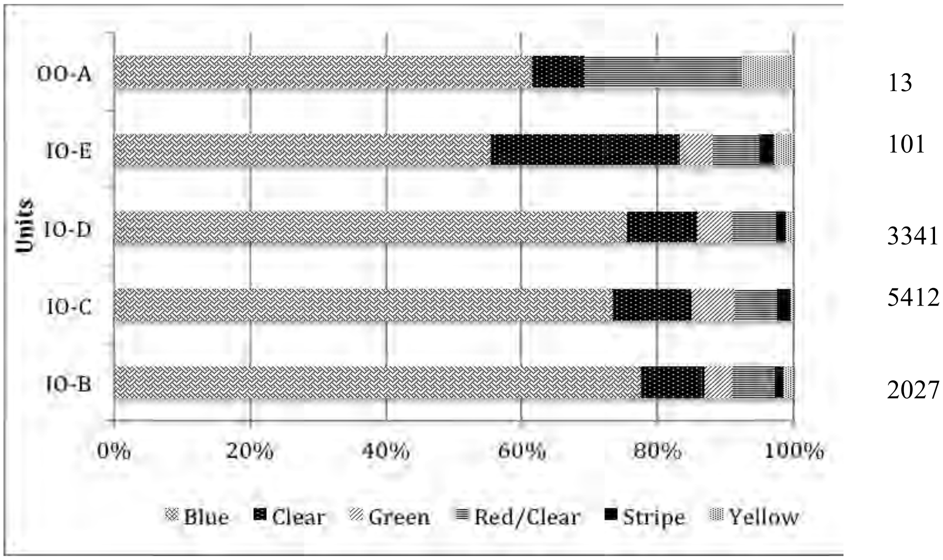


Figure 7.3. Frequency distribution of Igbo Olokun glass beads by color (note: the rare Black/gray category is omitted from the chart)

Approximately half of the beads in all Igbo Olokun units are cylinders; 30% are tubes including both treated and untreated, and the remaining c. 20% are oblates. In all shape groups and in all excavation units, 90% have diameters less than 5 mm. Beads with diameters greater than 5 mm are generally cylindrical in shape. Ends are either untreated or rounded through heating. No ground ends were detected. Snapped ends are most common among tubes (79%), which may indicate that some of the tubes represent production debris rather than untreated finished beads. Cylinders commonly have rounded ends (60%), and oblates always do. Since snapped ends only occur in tubes and cylinders, examination of these two shape categories reveals that snapped end is the most frequent (56%). All the beads were produced from drawn glass tubes, without exception. The surface of most of glass beads, especially the unfinished products, is characterized by striations parallel to the perforation, consistent with drawing a glass tube (Fig. 7.4). However, these striations are less visible on well-reheated finished glass beads.

The dichroic glass beads account for 2.2% of the beads studied. They occur in almost all the excavated levels in units B, C, and D and they occur in all three shape categories, having well rounded or slightly reheated ends (Table 7.2 & 7.3). Only a couple have an unfinished, snapped end.

Figure 7.4. Close-up of Igbo Olokun snapped tubular bead showing the surface striations.

Chemical Analysis of Igbo Olokun Glass Beads

A total of 71 glass materials were submitted to Dr. Laure Dussubieux of the Field Museum, Chicago, for analysis with laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) of major and minor oxides and trace elements. These samples included 49 glass beads. Where two glasses were present in a single bead (e.g. clear/red and clear/striped) each color was analyzed separately. Thus there are multiple results for several beads. In addition, 4 unperforated canes, 10 wasters, 7 crucible glasses, and 1 fragment of vitrified production debris (VPD)[1] were submitted for LA-ICP-MS analysis (See Appendix D.1). An additional 14 bead samples were analyzed by scanning electron microscopy (SEM) in the material science laboratory of Dr. Jim Meen at the University of Houston. Two other samples were analyzed by SEM with energy dispersive spectroscopy (EDS) at the Archaeological Material Science Laboratory of UCLQatar. In total 65 glass beads were chemically analyzed. The major criterion for selection of the chemically analyzed samples was representation of all excavation units including all shape groups and color categories (Fig. 7.5). All the samples are well

[1] These are vitrified clay. They are suggested to represent furnace ruins. See chapter 8 for detailed description and discussion of the results of the chemical analysis carried out on this class of materials.

preserved with smooth and shiny surface without corrosion. Those with corroded surfaces were deliberately omitted because of the understanding that corrosion may influence the composition measured using LA-ICP-MS (Dussubieux et al 2009: 160). In this section, I discuss the results of the bead analyses. The results of analyses on glass production materials are presented in Chapter 8. Dr. Dussubieux's report on the LA-ICP-MS analysis is presented in Appendix D.2.

Figure 7.5. Igbo Olokun glass beads analyzed by LA-ICP-MS

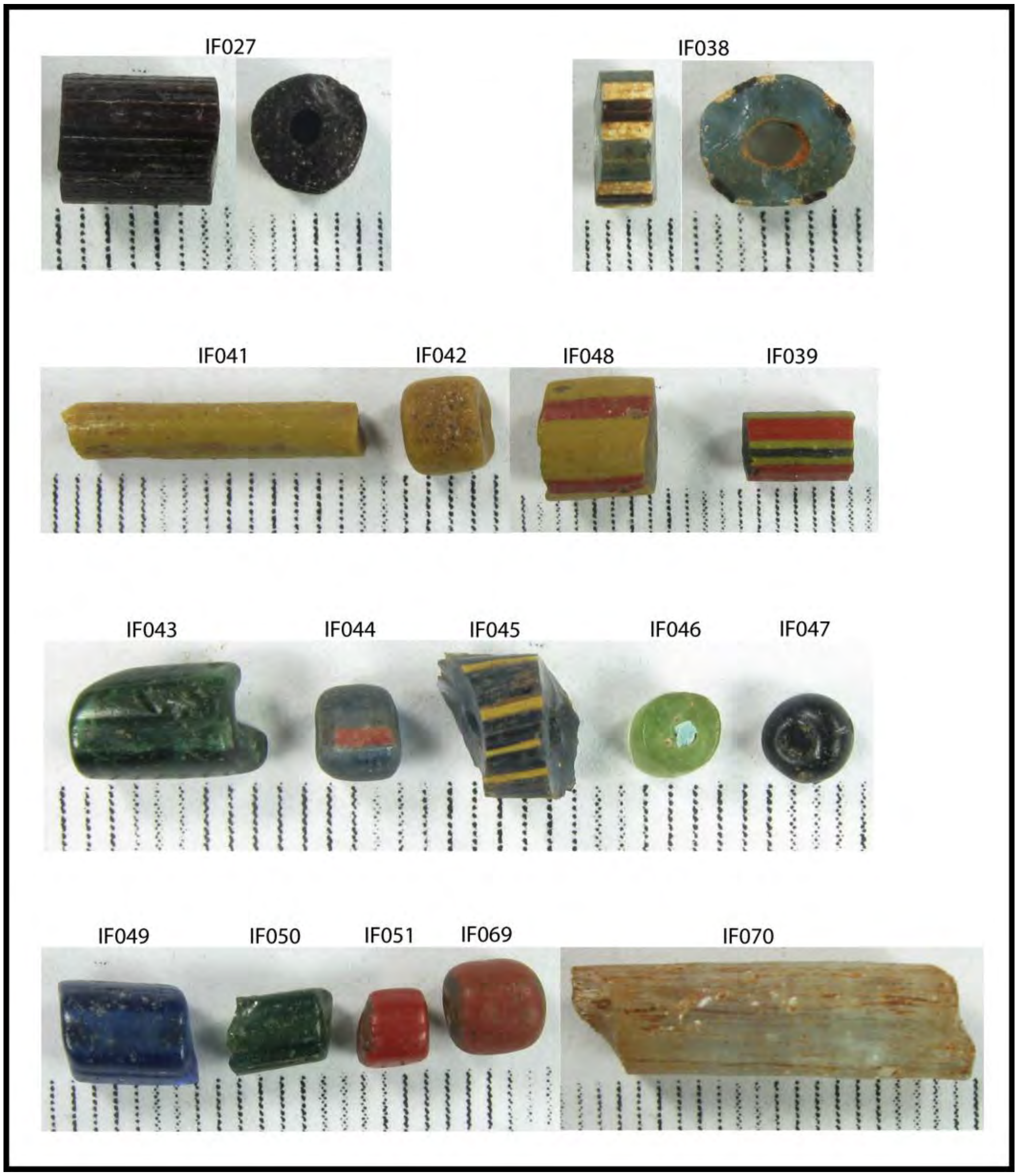


Figure 7.5 (Cont.). Igbo Olokun glass beads analyzed by LA-ICP-MS

Major and Minor Elements

The chemical compositions of the glass beads, comprising major and minor oxides and trace elements, are presented in Appendix D.3. As noted by Dussubieux (2013, Appendix D.2), the majority of the glass beads analyzed are high alumina glass, with Al_2O_3 ranging from 12-16 wt%. Most of the high alumina glass beads belong to the previously recognized high lime, high alumina (HLHA) compositional group (Davison 1972; Lankton *et al* 2006; Ige 2010a). The HLHA glass beads have 12-19 wt% lime (Fig 7.6). A smaller group of high alumina glass beads is characterized by lower lime content (<8 wt%). This group has been called low lime, high alumina (LLHA) (Ige 2010a & b;

Ige *et al.* under review) (Fig 7.6). The high concentration of alumina sets these two groups apart from European and Middle Eastern glasses, which have alumina levels of <3.5-4.0 wt%, as Brill (1987:4) noted. The HLHA glass beads are mostly transparent or translucent blue, olive or emerald green, and colorless. The LLHA group mostly occurs either as decoration (e.g., stripes) or, rarely, as whole glass beads. The LLHA glass beads are commonly opaque with yellow, dark gray/black, and dark red colors.

Soda and potash vary significantly in the samples (Fig. 7.7). Potash content and its negative correlation with soda may offer clues to the raw materials used in production. I expand on the discussion of the raw material for the production of Ile-Ife glass in chapters 8. Magnesia and phosphate are exceptionally low in HLHA glass and significantly higher in the LLHA group (Fig. 7.8), although still below the concentrations that would suggest plant ash as the source of alkalis for Ile-Ife glass (Lankton *et al* 2006; Ige *et al* under review). However, Tom Fenn (pers. comm. 2015) has suggested that reference to magnesia and phosphate levels for plant ash in glasses produced in the Near East and Europe may not be appropriate. The compositions of plant ash in Nigeria are not known, and they may differ from those from non-African sources.

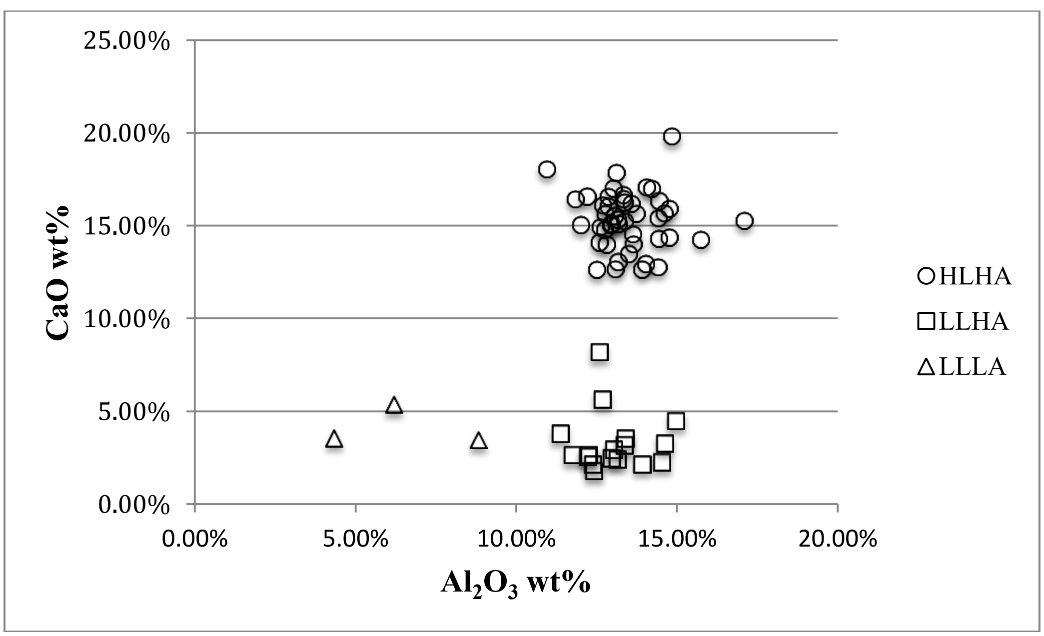


Figure 7.6: Alumina vs Lime content of Igbo Olokun glass beads, showing the two major groups and the sub-group.

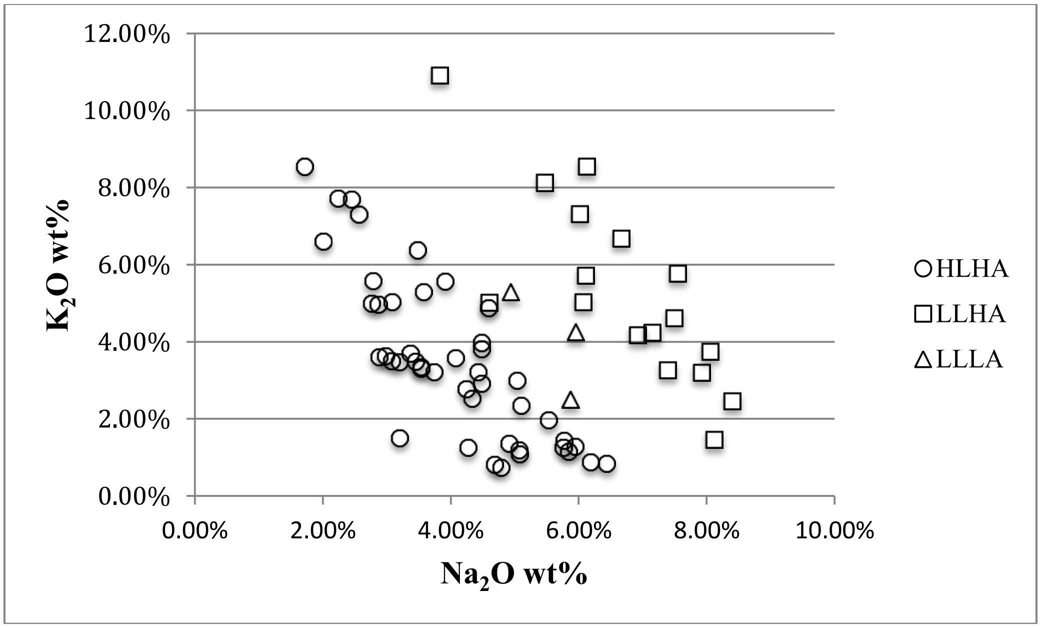


Figure 7.7: Soda vs potash content of Igbo Olokun glass beads, showing the variations of potash between the two major groups.

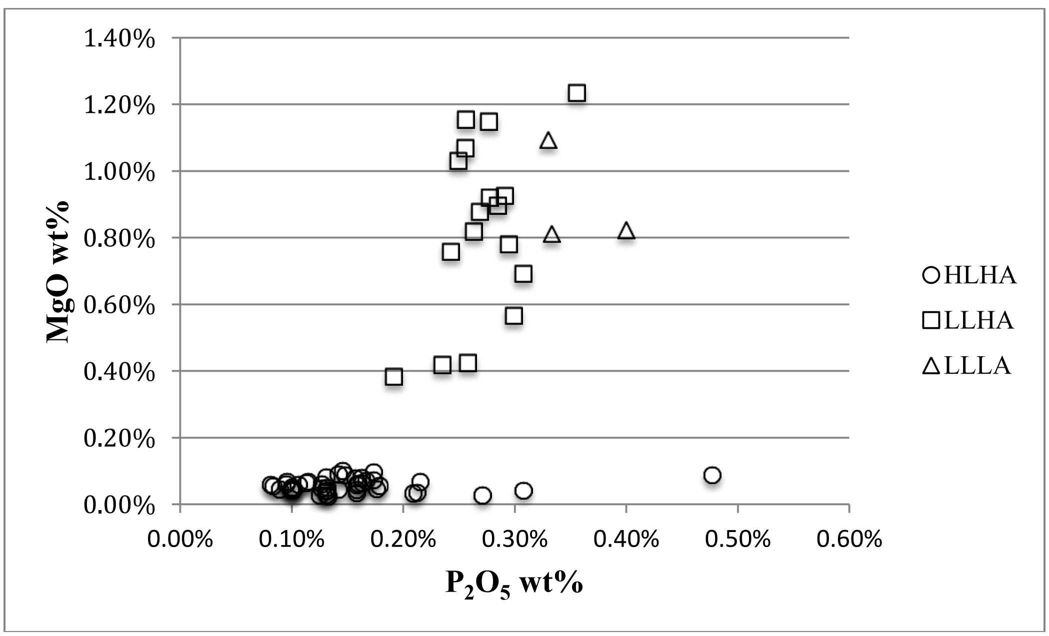


Figure 7.8: Phosphate vs Magnesia content of Igbo Olokun glass beads, showing the lower magnesia in the HLHA group.

A very few of the samples form another group with relatively low alumina (4–10wt%) and low lime (≤ 5wt%) (LLLA) (Fig 7.6). This compositional type only occurs in yellow and red stripes coating two glass bead samples with clear and pale blue cores. When other major and minor elements are considered, the LLLA group seems to have been a sub-group of LLHA because they share more characteristics with LLHA than the HLHA. These characteristics include the content of soda and potash, and magnesia and phosphate, as well as iron oxide. This third recognizable type may not represent another major group; rather it may be anomalies or variations in the chemical concentration in the LLHA group. Future analysis of more Ile-Ife glass beads, especially the uncommon colors, may help throw more light on this type.

Colorants, decolorizers, and opacifiers

About fifty-five percent of the analyzed glass beads are blues of different shades; all belong to the HLHA group. Most of the blue glass beads have elevated concentration of cobalt ranging from 200 to 1000 ppm. A few samples have cobalt levels between 1600 and 1900 ppm (Fig. 7.9). The question has been raised as to whether cobalt was added intentionally as colorant or whether it occurred naturally as an impurity in the raw material used for the glass beads (Ige *et al* Under Review). Henderson (2000: 29), for example, has noted that cobalt as low as 0.05 wt% (i.e. 500 ppm) is enough to give a deep blue color in soda-lime-silica glass. This percentage is probably also sufficient to produce shades of blue for the Ife high alumina glass beads. Dark blue beads have cobalt levels between 400 and 1000 ppm. Cobalt content below 400 ppm gives a pale blue color. When compared with LLHA, the HLHA blue glass beads exhibited high level of cobalt, while LLHA glass beads have higher concentrations of iron and copper (Fig 7.10). This indicates that cobalt was used as a colorant for shades of blue.

Among the LLHA glass, dark opaque red and yellow appear to have a higher concentration of iron, which is connected to a higher concentration of copper. The high content of these two oxides in the LLHA glass shows that they may have been selected to produce dark red or yellow colors. It is yet uncertain whether or not lead-antimonate was used in the yellow glass beads.

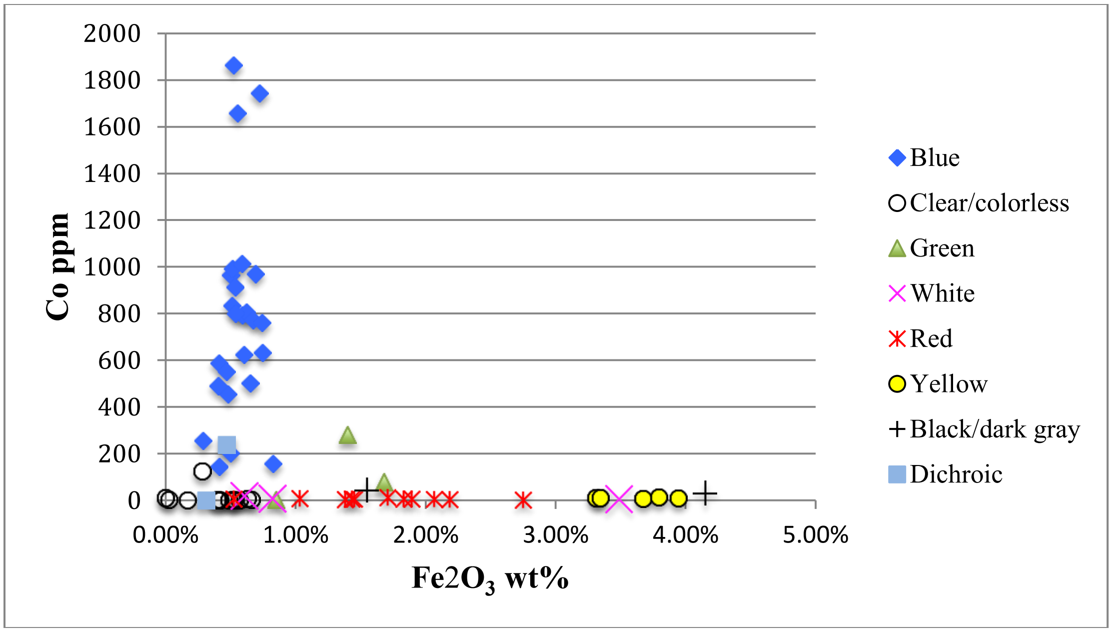


Figure 7.9: Iron vs cobalt content of Igbo Olokun glass beads, showing cobalt as a colorant in the HLHA blue glass.

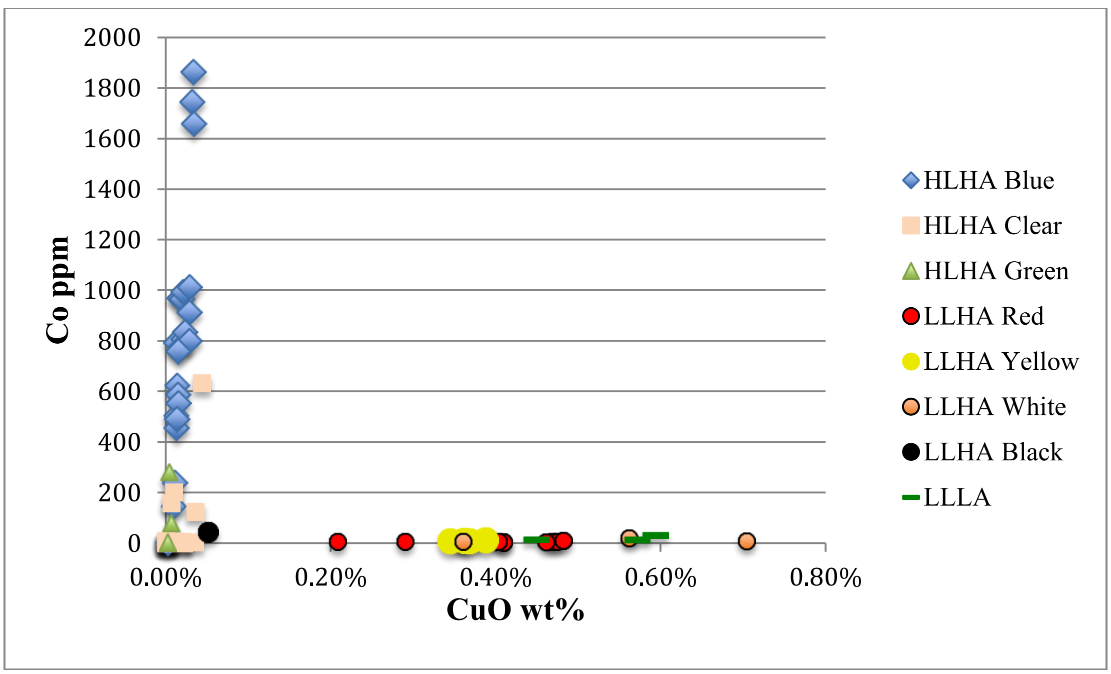


Figure 7.10: Copper vs cobalt content of Igbo Olokun glass beads by color and compositional category. The LLLA group includes red, yellow, and black beads.

The concentrations of manganese and antimony vary significantly among the glass beads analyzed. More importantly, the levels of MnO and Sb in the HLHA clear/colorless glass are very low (mostly <0.2 wt% for MnO and <2 ppm for Sb) (Fig. 7.11). The very low content of MnO and Sb in the clear glass beads is connected with elevated iron, although not exceeding 0.7%.

Manganese and antimony are decoloring agents used in ancient glass. These oxides are major decolorizers intentionally used in Roman glass (Jackson 2005; Baxter *et al* 2005). However, the significantly low level of antimony in the HLHA clear glass beads from Ile-Ife with low content of manganese and higher iron concentration do not suggest intentional addition of any of the decolorizers. It is possible that these oxides were present naturally in the raw materials. The low concentration of these oxides may also suggest that the raw materials have very low impurities, which gives the glass its colorless appearance. If this was the case, the craftsmen would have intentionally exploited the particular source of raw material for making clear glass.

The LLHA and LLLA glass beads, most of which are dark colors (dark red, yellow, white, and dark gray/black) and opaque, have low manganese content. The low manganese is connected with higher iron and antimony. There is also elevated lead ranging from 0.04 to 0.07wt%. There is a single case of white glass with lead level of 13wt%. This high lead glass bead may be imported (Fenn 2015 pers. comm.). However, the overall low level of these oxides makes it difficult to affirm that they were used as opacifiers. Individual detailed chemical analysis of different color categories may shed more light on this.

From the analysis, cobalt seems to have been used as a blue glass colorant. The ingredients for other colors, as well as decolorizers and opacifiers used, are unclear. For example, was copper added deliberately as colorant? Was the colorless achieved by accident due to less impurity in the raw materials or intentionally decolorized? Which ingredient was used as an opacifier?. Further investigations will focus more on these areas.

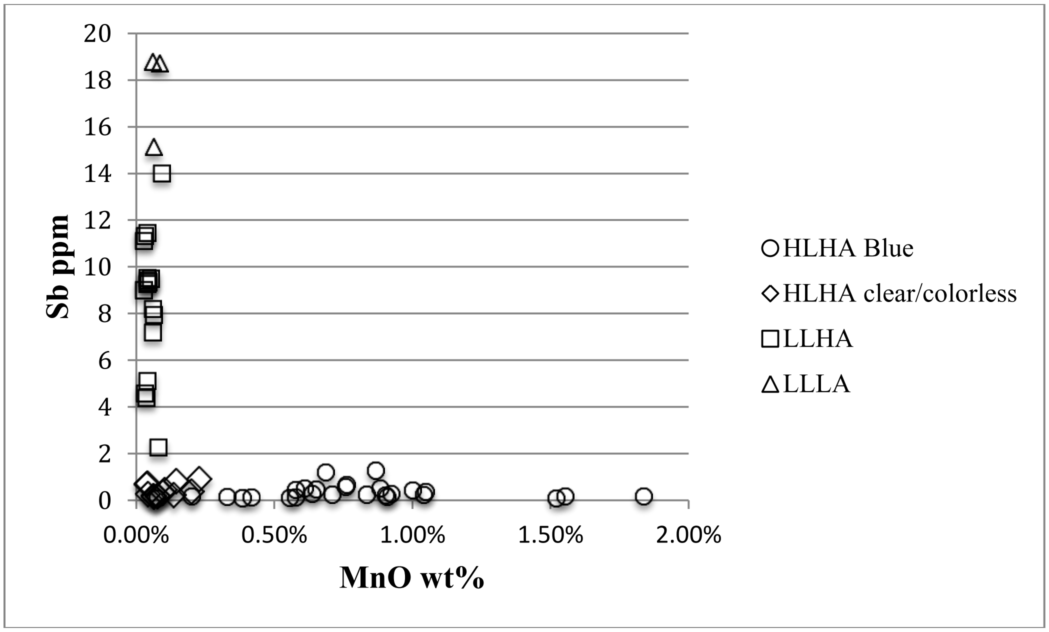


Figure 7.11: Manganese vs antimony content in Ile-Ife glass.

Trace elements

Results of the trace elements from our analysis expand the limited data available for Ile-Ife glass beads. Recent analyses (Ige *et al* under review) have suggested that trace elements such a rubidium and strontium are potentially significant for our understanding of local primary glass production at Ile-Ife. Specifically, Ige *et al.* (under review) propose that Ile-Ife glass beads have a distinctively high rubidium signature (50–400 ppm). The rubidium is contributed by the local raw material used in glass making. Strontium appears to be positively correlated with lime levels. The source of the strontium in Ife glass is suggested to be snail shell used as a source of lime.

Consistent with the observations of Ige *et al.* (under review), the content of rubidium in Igbo Olokun glass beads also clusters between 50 to 400 ppm, with a few cases between 400 and 750 ppm (Fig 7.12). The correlation of lime and strontium indicates that the lime is the source of the strontium (Fig. 7. 13). There are, however, a few samples with much lower lime and high strontium.

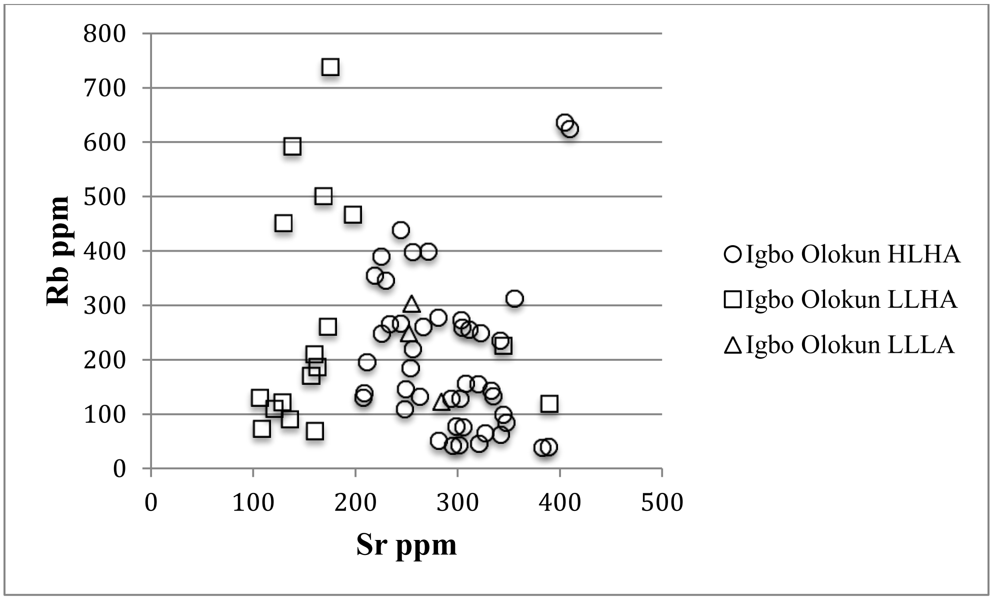


Figure 7.12: Strontium vs Rubidium content in Ile-Ife glass beads.

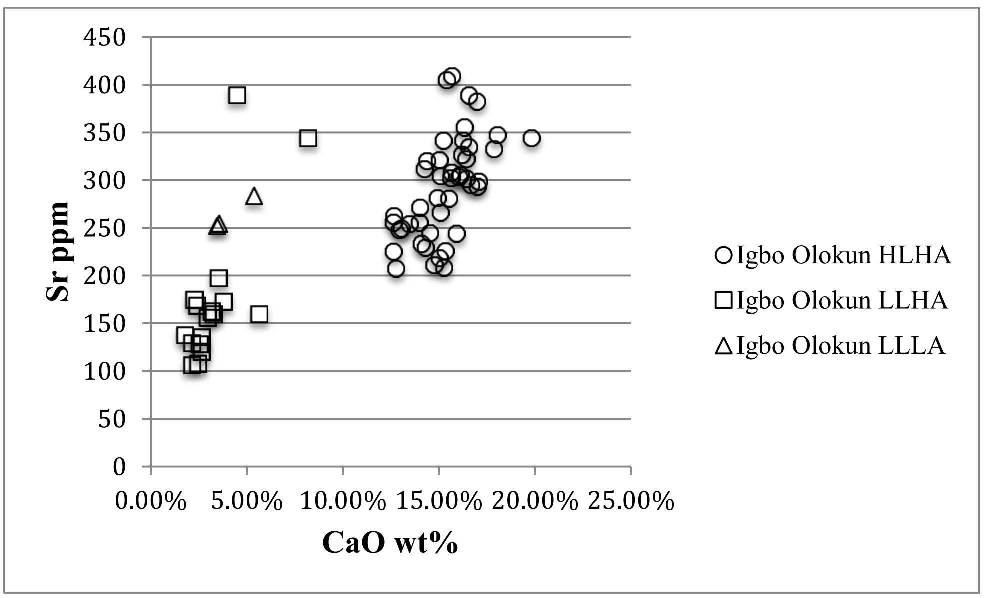


Figure 7. 13: Lime vs strontium content in Ile-Ife glass beads.

Comparison of Igbo Olokun and other glass beads from Ile-Ife and Yorubaland

Various excavators in Ile-Ife have reported glass beads and offered some elements of description or further analysis: Willett (1959; 1970; 2004) in Oru Oba Ado and Ita Yemoo; Garlake (1974, 1977) in Obalara and Woye Asiri; and Eluyemi (1987) in Igbo Olokun. Other collections have been made of surface finds from different sites in the city (e.g., Ige 2010a). In addition, glass beads incorporated into *aje ileke*, plaques of remelted glass beads and cullet from the interior of crucibles, have been purchased in the Ife market (Lankton *et al*. 2006). There are also glass beads in the Ile Ife collection at the British Museum (Lankton *et al*. 2006). For many of these, the find context is poorly known, if at all, and systematic descriptions of color, shape, size, and other formal attributes are rare. I begin with an overview of what is known of the physical characteristics of glass beads from other excavations and surface collections in Ile-Ife and compare them to the assemblage excavated from Igbo Olokun, I then compare the available chemical composition data for these other Ile-Ife beads with those for the Igbo Olokun excavated beads.

Determining the chronology of the various beads is difficult because of a lack of detail on context, when known, and uncertainty over the association of dated carbon samples and the beads. Various sites in Ile-Ife, including Igbo Olokun, have been subject to digging for glass, reworking of glass, and possible reburial of crucibles (Willett 2004). Dates as early as the seventh century A.D. have been obtained from Oru Oba Ado; most other sites with glass beads in Ife have been radiocarbon dated to between the 11th and 15th centuries A.D. Osogbo, a site 40 kilometers north of Ile-Ife, has recently provided well-dated evidence for glass beads and likely primary glass production dated to the 17th-18th c. (Ige *et al*. under review). This work is significant because it presents the first detailed compositional analysis of glass beads in Yorubaland outside Ile-Ife. It provides an important point of comparison with the Ile-Ife beads.

Willet (1970, 2004) reported numerous glass beads from Orun Oba Ado, Ita Yemoo and Igbo Olokun but provides little descriptive information. Photographs, particularly those of individual beads analyzed by Davison (1972) and Lankton *et al* (2006) provide the only information we can glean. In addition, Eluyemi (1987) and Ige (2010a) have also provided some limited descriptive information on Ile-Ife glass beads.

As shown in Table 7.4, some physical characteristics of previously reported Ife glass beads follow the same trend with those in our assemblage. The color descriptions, and some motifs on the beads are largely comparable. The assemblage from Igbo Olokun is also comparable in term of colors with Eluyemi's (1987) 180 glass beads excavated from Igbo Olokun. Davison's (1972: 251) multicolor bead (ITA-19) has no counterpart in our assemblage. The description of some black beads among those analyzed by Brill for Ige also matches with black in the Igbo Olokun assemblage.

Red/clear beads make up just under 10% of the Igbo Olokun beads, while solid red beads are rare. When red beads are reported in the literature (e.g., Eluyemi 1987) it is not clear whether they are solid red or red over a clear core.

Eluyemi's (1987) work on the excavated and surface collected glass beads from Igbo Olokun appears to be the only literature that reports the shapes of Ife glass beads for a fairly large assemblage. Unfortunately, his shape categories (Table 7. 5) are somewhat idiosyncratic (e.g., "C-type" and "J-type") and no illustrations are provided. His dominant categories are tubes and cylinders, which is broadly consistent with the Igbo Olokun assemblage for the current study. Future work on beads will be facilitated by the use of standardized shape categories.

Eluyemi's assemblage also matches our assemblage from Igbo Olokun in bead size, with very few beads >5mm in diameter. Interestingly, beads that exceed 5 mm in diameter are dominant among the photographed beads from Ita Yemoo that could be measured; however, this may be due to selective recovery of larger beads in an excavation that did not use fine-mesh sieving, and also a preferential selection for photography of larger beads. Larger diameter beads/tubes were dominant on *aje ileke* analyzed by Lankton *et al.* (2006). The very long tubes in the *aje ileke* as well as those described by Brill (Table 7.4) are likely to represent manufacturing debris rather than finished beads. Glass tubes or canes missed in the production chain or shattered while processing are expected to have a longer length.

These identified similarities and differences between our assemblage and the previous works are worth noting. However, their significance is unclear, because numerous factors, including small sample size and possible recovery and reporting biases, affect the previous assemblages. A much larger sample of beads from other locales in Igbo Olokun and other sites, analyzed and described using a standardized approach to both the physical characteristics and the compositional analysis will help clarify this.

Sites	Color	Length (mm)	Diameter (mm)	Shape	Ref. #	Comments
Davison1972[a]						
Oru Oba Ado	Cobalt-blue	11	7	Long cylinder	ORU-82	With red stripes
Ita Yemoo	Blue-green	5	10	Short cylinder	ITA-65	
Ita Yemoo	Black (Dark green)	10	9	Barrel	ITA-27U	
Ita Yemoo	Blue-green	4	7	Short cylinder	ITA-914	
Ita Yemoo	Blue	6	6	Reheated cane	ITA-20	With white stripes framed by red
Ita Yemoo	Yellow	10	6	Biconical	ITA-22B	
Ita Yemoo	?	7	6	?	ITA-19	Composite bead of red, green, and yellow
Ita Yemoo	Cobalt-blue	16	5	Cane	ITA-27F	
Ita Yemoo	Dichroic	10	5	Cane	ITA-1411	
Lankton et al. 2006						
Olokun grove[b]	Dark blue	23	10	Large	BM19a	
Olokun grove[b]	Dark greenish-blue	65	5	Very long	BM19c	Diameter tapers from 5mm to 2.5mm
Olokun grove[b]	Medium blue	20	5	?	BM19d	
Aje Ileke 1[c]	Light blue	15	5	?	IF1B	
Aje Ileke 1[c]	Dark blue	12	7	?	IF1D1	
Aje Ileke 1[c]	Dark blue	5	5	?	IF1D3	
Aje Ileke 1[c]	Dark blue	10	5	?	IF1D2	
Aje Ileke 3[c]	Yellowish green	22	5	?	IF3.1	
Aje Ileke 3[c]	Medium green	40	6	?	IF3.2	
Aje Ileke 3[c]	Pale green	20	6	?	IF3.3	
Aje Ileke 3[c]	Pale green	11	7	?	IF3.4	
Brill 1998[d]						
Ile-Ife	Black	45	7	?	9020	
Ile-Ife	Black	41	9	?	9021	
Ile-Ife	Black	29	12	?	9022	
Ile-Ife	Black	24	6	?	9023	
Ile-Ife	Black	35	8	?	9024	
Ile-Ife	Med. Blue	46	6	?	9025	

Ile-Ife	Med. Blue	38	11	Elliptical	9026	Possible ground ends
Ile-Ife	Green	47	22	Irregular	9027	
Ile-Ife	Clear	?	22	Spherical	9028	
Ile-Ife	Black	?	20	Spherical	9029	
Ile-Ife	White	?	28	Spherical	9030	

Table 7.4. Ile-Ife glass beads sampled and described by Davison (1972) and Lankton *et al.* (2006), and Brill (1998). Note: [a] = samples from Frank Willett's excavations, [b] = Samples originated from the British Museum's collection, [c] = *Aje Ileke* were bought in Ile-Ife in the 1990s by one of the authors. The authors did not give information on the exact size of the samples. I measured the samples from the illustrations in the paper with the scale provided. Although Lankton *et al.* describe all the beads from the *aje Ileke* as "short cylinders", the measurement shows that they are mostly tubular. It is likely that Lankton *et al.* analyzed different bead samples from the *aje ileke* that are not obvious from the illustration. However, their color description matches with the illustration; [d] = No exact provenience information is provided. Samples were collected or dug up from around Ile-Ife by A. Ige.

Site	**Shape**
Olokun grove	Tubular
	Tube-like
	Tubular twin
	Circular
	Circular and flat
	Round
	Ring-like
	Letter C type
	Letter J type

Table 7.5. Shape categories of the glass beads excavated and surface collected by Eluyemi at Igbo Olokun.

Comparison of the chemical composition of Igbo Olokun assemblage with other sites in Ile-Ife

Davison (1972) was a pioneer in chemical composition analysis of African glass beads. She analyzed a significant number of beads excavated by Willett from Orun Oba Ado, Ita Yemoo, and Igbo Olokun using neutron activation analysis (NAA) and X-ray fluorescence (XRF) analysis. Here we discuss the data from NAA since the element(s) analyzed with XRF are not of direct relevance for our studies. Davison's data on element concentrations were converted to oxide weight percentages so they are directly comparable with the Igbo Olokun data.

For precision, Davison (1972: 33) considers elements with "counting error greater than 20% of the concentration in one-third or more of the samples" as imprecise. She therefore omitted those elements from the table or noted them as present or absent. This decision, resulting from limitation of the analytical techniques at the time, left out important elements essential for interpretation of the results. For example, potash and lime are not provided for an entire group, and magnesium was not given for all the samples analyzed. The non-inclusion of these elements raises a challenge in understanding the composition of raw materials and production processes for Ife glass beads. Despite the challenges Davison faced in her analysis, her work is still very valuable for comparison with our data from Igbo Olokun.

Based on the consistency of some compositions, Davison identified three chemical groups, I, II, and III, from her samples (Appendix D.4). Group I comprises HLHA glass, with concentrations of 10 to 18 wt% for both lime and alumina (Fig. 7.14). Most of the Group I beads have high potash above 5wt% with low soda often below 4.5 wt% (Fig. 7.15), although with very few exceptions. Davison identified a sub-group (IA) characterized by dichroism and/or striations on the surface ("corded" beads). Both share the chemical composition of Group I (Davison 1972: 249). The correlation of manganese and cobalt is another distinguishing aspect of Group I, with varying iron concentrations. The concentration of iron and cobalt strongly suggests these element as colorants for this group (Davison 1972: 255) (Fig. 7.16).

Group II is soda-lime glass and Group III consists of two beads that do not belong to either of the first two groups in Davison's classification (1972: 258).

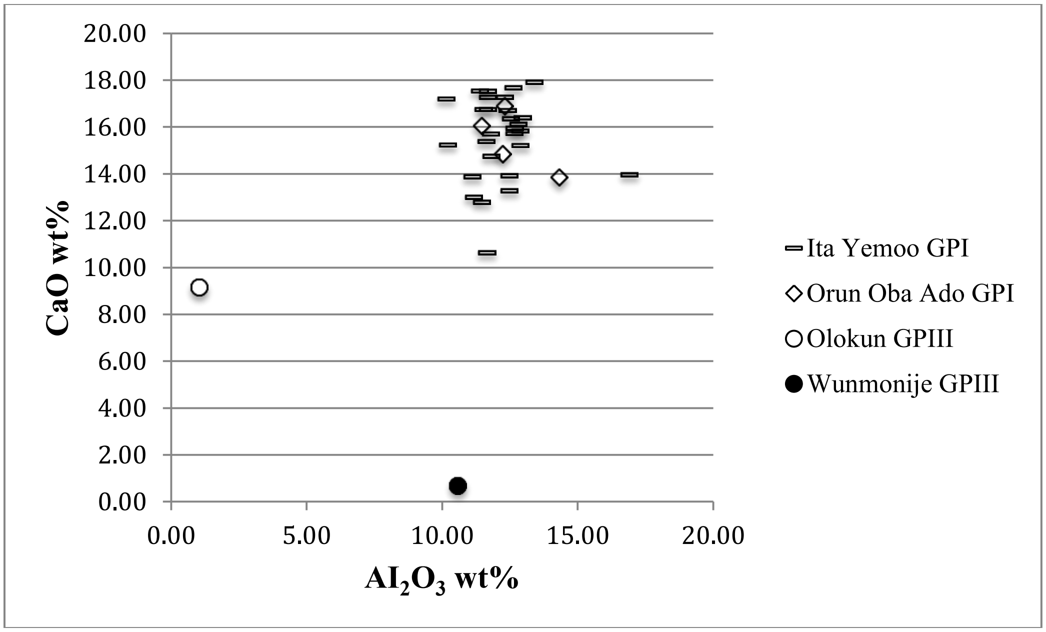


Figure 7.14: Alumina vs lime content of Ile-Ife glass beads analyzed by Davison (1972) showing Group I with HLHA, and Group II with low alumina.

Note: Davison did not report the CaO values for all the samples in group II, although she indicates in note that group II has an upper limit of 7.7 + 1.7(elemental) %, which is 10.7wt% when converted to oxide (Davison 1972: 298). Therefore group II is not represented in this chart. . (GP = Group)

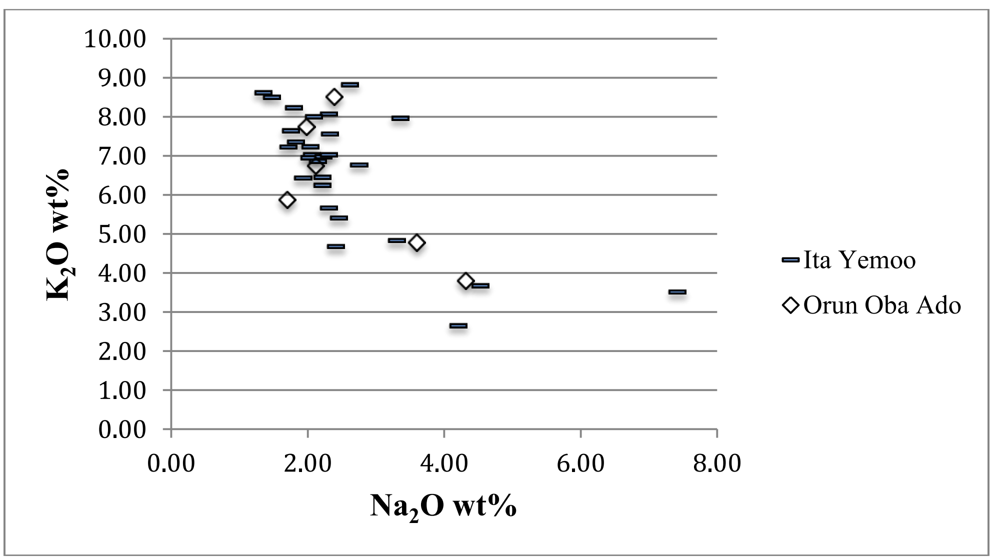


Figure 7.15: Soda vs potash content of Ile-Ife Group 1 glass beads analyzed by Davison (1972).

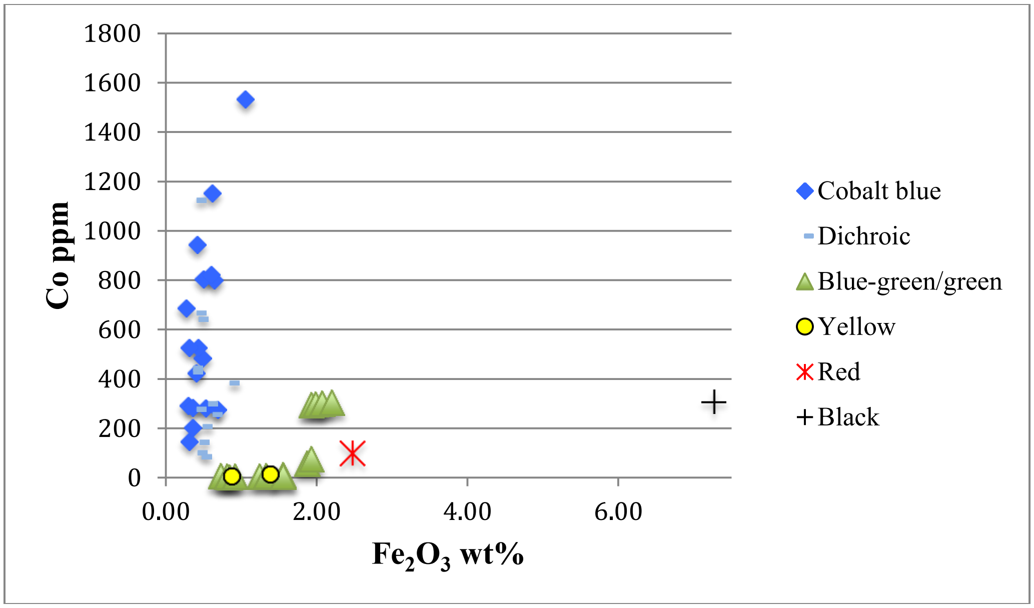


Figure 7.16: Iron vs cobalt content in Ile-Ife glass beads analyzed by Davison (1972), showing elevated cobalt in shades of blue and elevated iron in other colors.

Based on the concentration of lime and alumina, it is evident that the HLHA glass bead assemblage from Igbo Olokun is chemically similar to Davison's Group I from Ita Yemoo and Orun Oba Ado (Fig 7.17; 7.18). Davison's Group II, with soda content between 10-20%, is absent from the Igbo Olokun sample.

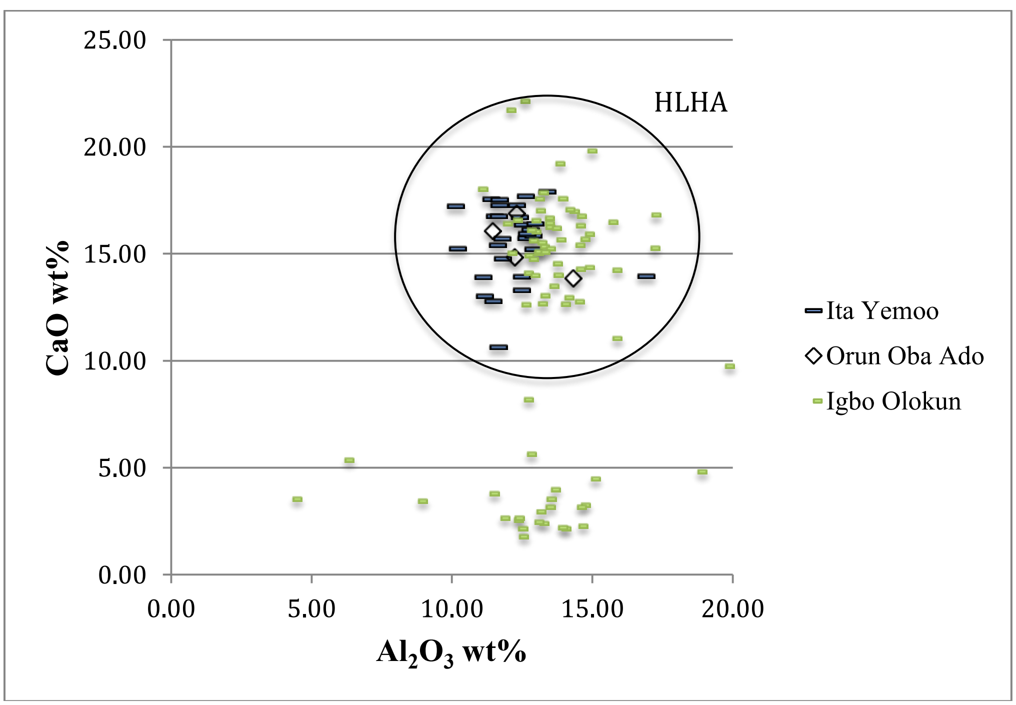


Figure 7.17: Alumina vs lime content in Ile-Ife glass beads comparing Davison's Group I with Igbo Olokun assemblage

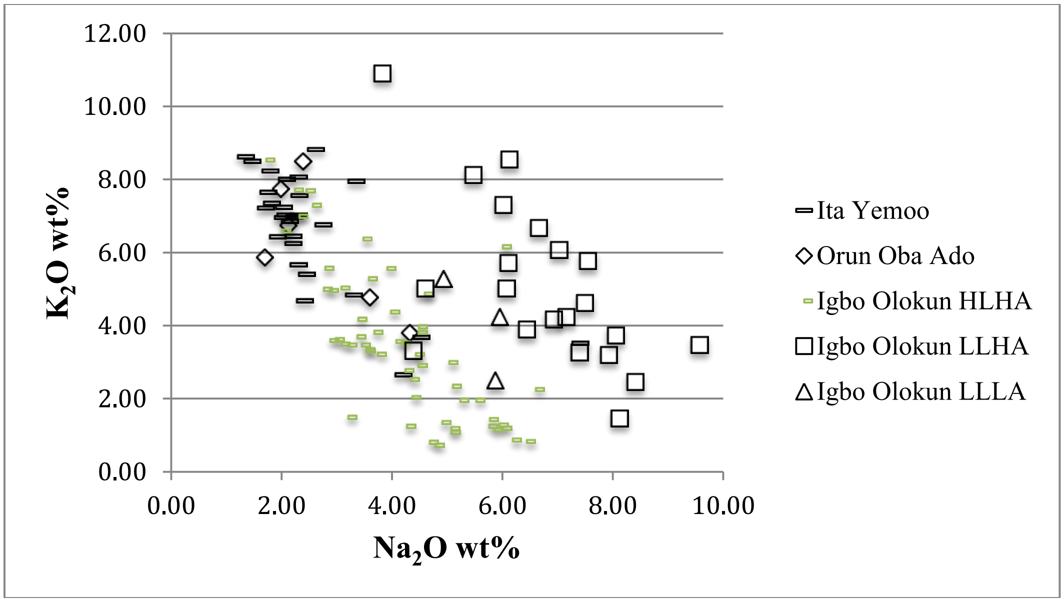


Figure 7.18: Soda vs potash content of Ile-Ife glass beads comparing Davison's Group I with Igbo Olokun (GP = Group). Davison's Groups II and III have between 10 and 20 wt% of soda (when converted to oxide), but potash was not reported for Group II.

The more recent work of Lankton *et al*. (2006) has provided additional significant data on the composition of Ile-Ife glass beads using SEM/EDS, electron probe microanalysis (EPMA) and XRF. I have discussed their work in detail in chapter three in the context of glass production in Sub-Saharan African. For EPMA, Lankton *et al.* (2006: 118) checked precision and accuracy by using several glass standard, and specifically for SEM/EDS they generally were "within 10% for elements present in amounts greater than 1%, and closer to 20% for elements present at lower levels".

Lankton *et al.* (2006) analyzed fifteen glass bead samples of probable Ile-Ife origin, which were acquired from different sources within and outside Ile-Ife (Table 7.4). None was from an identified archaeological context. Based on the concentrations of certain major and minor elements, Lankton *et al.* identified five groups within three major classes: high lime high alumina (HLHA), high lime low alumina (HLLA), and soda-lime glass (Appendix D.4). The HLHA beads form a significant cluster (Fig. 7.19), with soda levels below 8 wt% and potash varying from 2.5–6 wt% (Fig. 7.20). A soda content between 12–17 wt% distinguishes the soda-lime glass group from others. With the exception of few HLLA with elevated magnesium, the three groups seem to be significantly low in phosphate and magnesium to the point that they are not detected in some of the samples (Fig. 7.21).

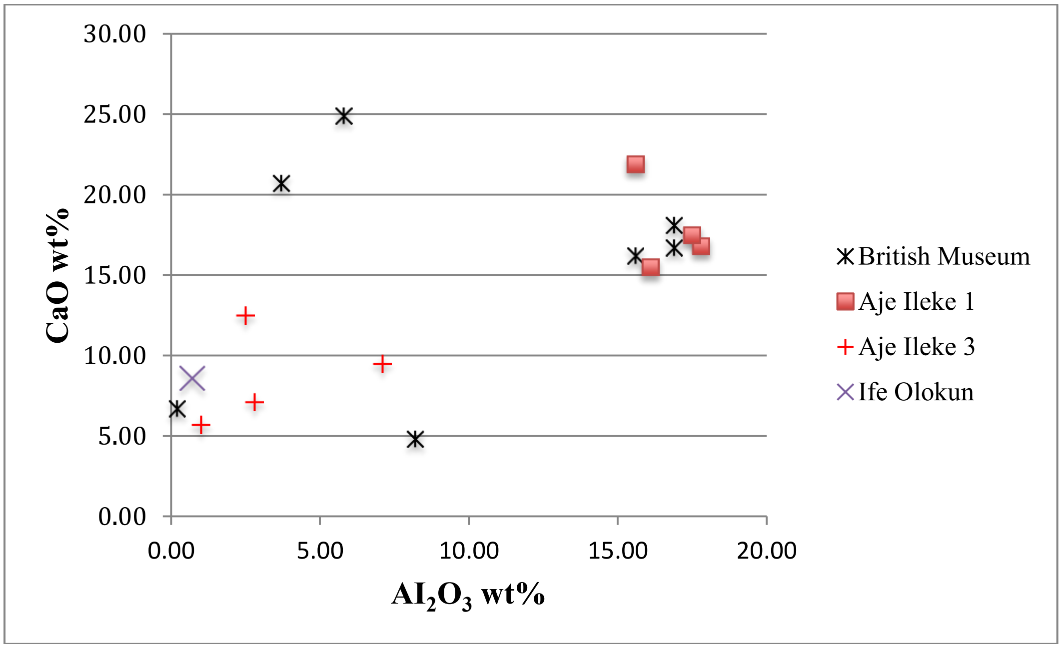


Figure 7.19: Alumina vs lime content of Ile-Ife glass beads analyzed by Lankton *et al*.

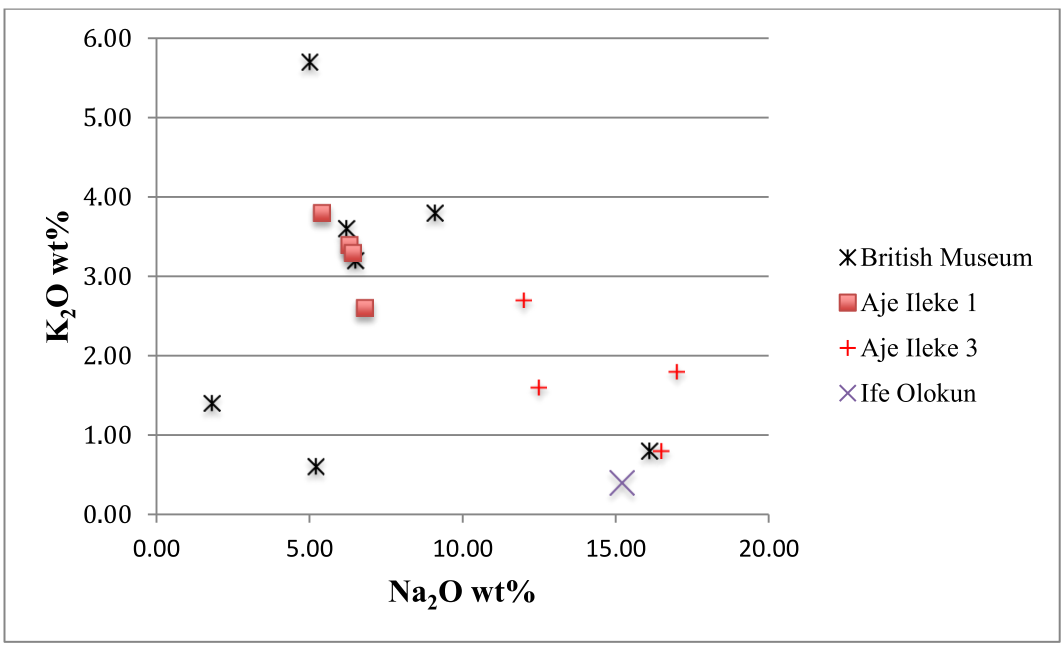


Figure 7.20: Soda vs potash content of Ile-Ife glass beads analyzed by Lankton *et al.*, showing the group with high soda (>12 wt%).

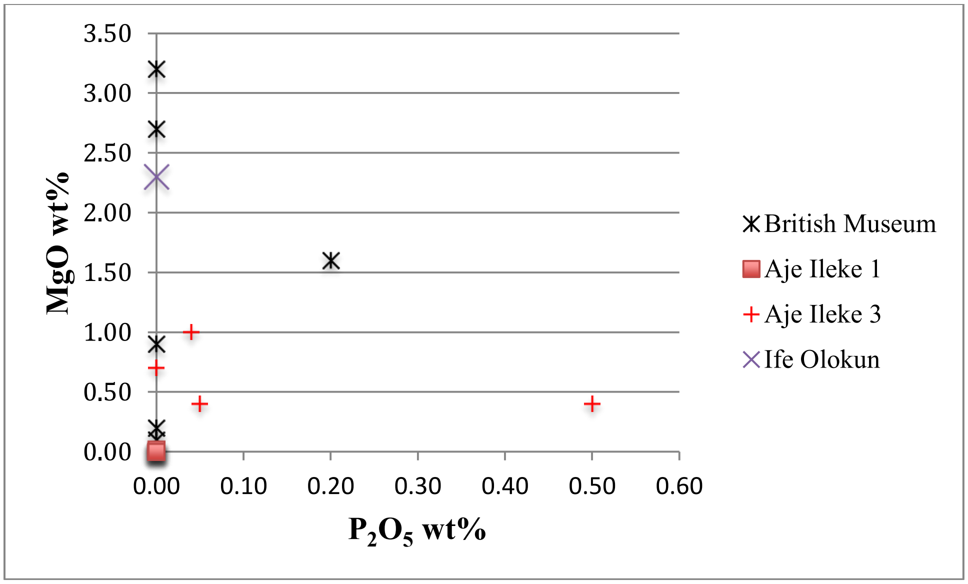


Figure 7.21: Phosphate vs magnesia content of Ile-Ife glass beads analyzed by Lankton *et al.*, showing the high magnesia group. Note: Lankton *et al* (2006) recorded phosphate value for most of the samples as not detected (nd), represented here by a value of zero.

The analyses that have been carried out on Ile-Ife glass beads document the presence of several different glass compositions, with soda, alumina, lime and magnesia as the major differentiating oxides (Table 7.6).

Low Soda, Low Magnesia glass					
	Wt % range of major oxides				
Glass group	NaO2	Al2O3	CaO	MgO	K2O
HLHA	1–6	10–18	10–22	0–0.15	0.5–9.0
LLHA	3–8	12–19	1–8	0.4–1.7	1–11
LLLA[a]	2–6	4–8	3–5	0.8–1	2–5
Low Soda, High Magnesia glass					
HLLA[b]	1–6	3–6	20–25	2.7–3.2	0.5–1.5
High Soda glass					
LLLA,Low MgO[c,d]	12–20	1–7	4–10	0.1–1	0.2–2.7
LLLA,High MgO[e]	9–15	0.2–0.7	4–9	1.6–2.3	0.4–3.8

Table 7.6. Summary of major oxide ranges by weight percentage in Ile-Ife glass bead composition groups ([a] from Igbo Olokun; [b] samples BM291, 293; [c] *aje ileke* samples and BM279; [d] Ife samples 9020-9028; [e]IFOG,BM17.2 – [b,c,e] data from Lankton et al. 2006; [d] data from Brill)

Most of the analyzed beads belong to the HLHA group (Fig. 7.22), which has soda levels under 10% (Fig. 7.23). The LLHA group is represented primarily at Igbo Olokun. No provenience information is provided on the LLHA beads Brill analyzed for Ige. So we cannot say precisely where within Ile-Ife the samples originated. The LLLA group includes both high soda glass (aje ileke3, British Museum and Ife samples analyzed by Brill) and low soda glass (Igbo Olokun).

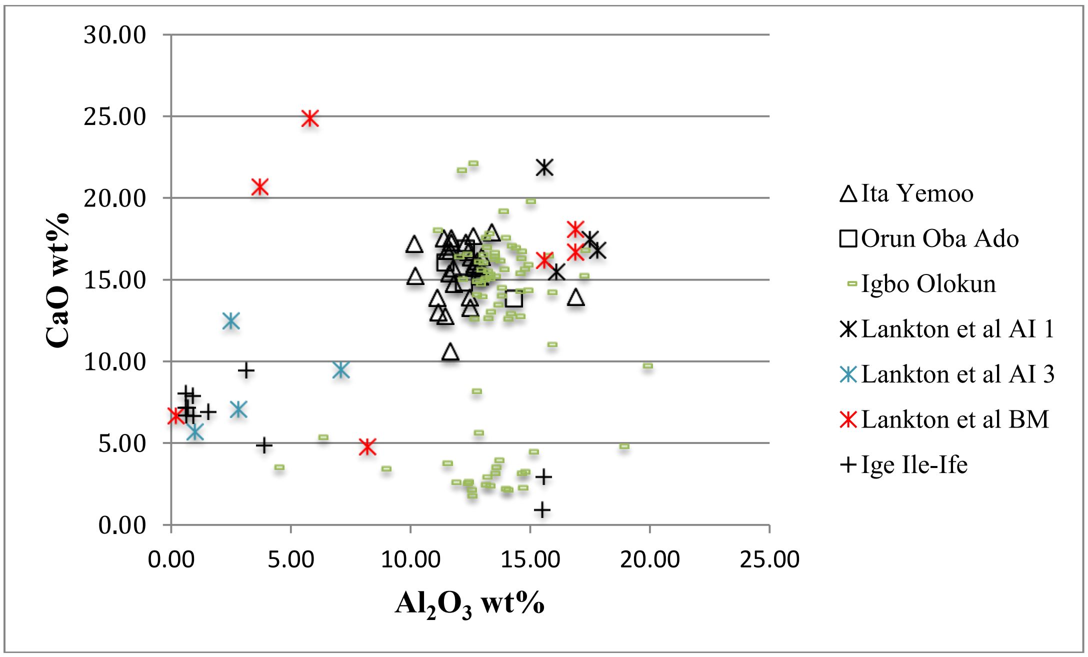


Figure 7.22: Alumina vs lime content of Ile-Ife glass beads, showing the distinction of the major group (HLHA), and to a lesser extent LLHA. (AI = *Aje Ileke*, BM = British Museum). **Note:** Davison did not report the CaO values for all the samples in group II, although she indicates in note that group II CaO has an upper limit of 10.7wt% (Davison 1972: 298). Therefore group II is not represented in this chart.

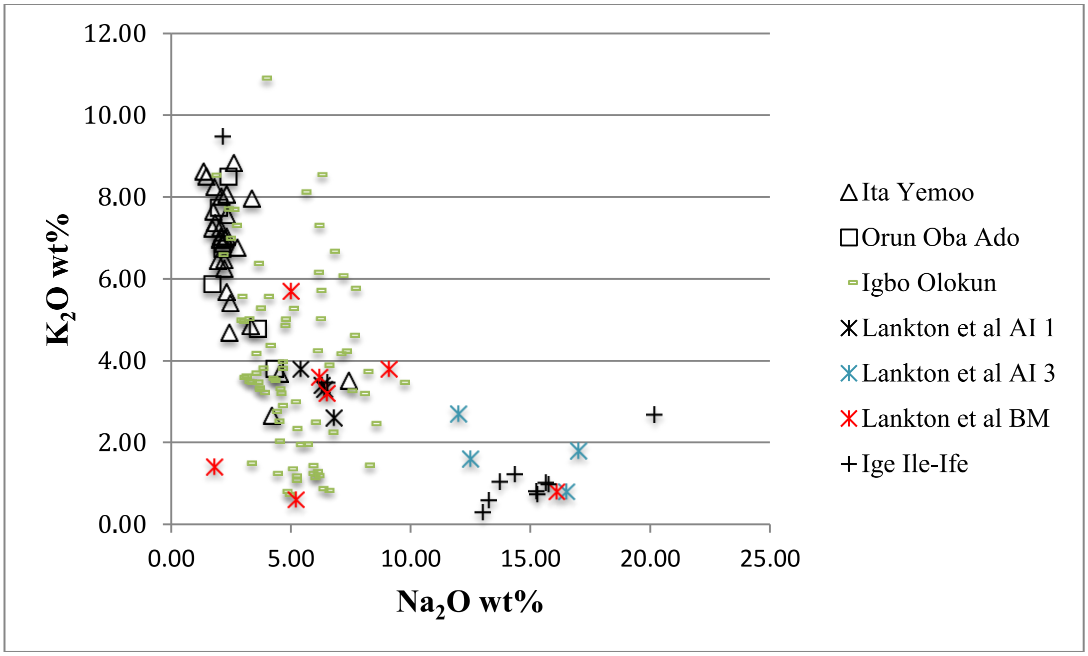


Figure. 7.23: Soda vs potash content of Ile-Ife glass beads, showing the overlapping of both oxides, and the soda-lime glass, particularly at Ita Yemoo, Orun Oba Ado, and among Lankton *et al.*'s samples. **Note:** Davison did not report the K_2O values for the samples in group II, so group II is not represented in the chart.

The compositional analysis of glass beads from our excavations in Igbo Olokun has greatly contributed to our knowledge of different chemical groups that exist in the ancient city (Table 7.7). The occurrence of HLHA in many sites in Ile-Ife demonstrates the preponderance of the HLHA glass beads in ancient Ife, as well as, so far, the localization of LLHA to Igbo Olokun. But were the HLHA and LLHA groups limited to Ife in the Yoruba region? In other words, how does the Igbo Olokun glass bead assemblage compare to glass beads known from outside Ile-Ife? To examine this, I next compare the chemical composition of the Igbo Olokun materials with those from early Osogbo, southwest Nigeria.

	Igbo Olokun	Orun Oba Ado	Ita Yemoo	*Aje Ileke*1	*Aje Ileke* 3	British Museum	Ife (Ige)
HLHA	X	X	X	X		X	
LLHA	X						X
LLLA	X						
HLLA						X	
HIGH SODA		X	X		X	X	X

Table 7.7 . Summary of glass composition groups documented from Ile-Ife sites.

Comparison of the chemical composition of Igbo Olokun assemblage with materials from outside Ile-Ife

Within the Yoruba region outside of Ile-Ife, not much research has been done on the chemical composition of archaeological glass beads. However, the recent recovery of glass beads of similar physical attributes to Ife glass beads from a 17th-18th century A.D. site in Osogbo is a major contribution to our knowledge of glass bead production in early Yorubaland (Ogundiran 2014; Ige *et al.* under review). Ige *et al.* (under Review) chemically analyzed 18 glass beads from secure archaeological contexts in Osogbo with 12 samples from Ile-Ife for comparison. The authors stated that the 12 Ile-Ife glass bead samples are from Igbo Olokun, however, they did not give any information about their archaeological context. Since no archaeological excavation has been reported on the site for almost three decades, the samples could have been collected at the surface of Igbo Olokun. Analysis of these samples reveals the dominance and similarity of the HLHA group in both the Osogbo and Ife samples (Fig. 7.24). The similarities indicate a common source of raw material and a continuous tradition of glass making/working in Yorubaland from the 11th through early 18th centuries. One analyzed Osogbo bead corresponds to the LLHA group (Fig 7.24), and shares with the Igbo Olokun LLHA beads elevated magnesia, phosphate, iron, and copper (Ige *et al.* under review).

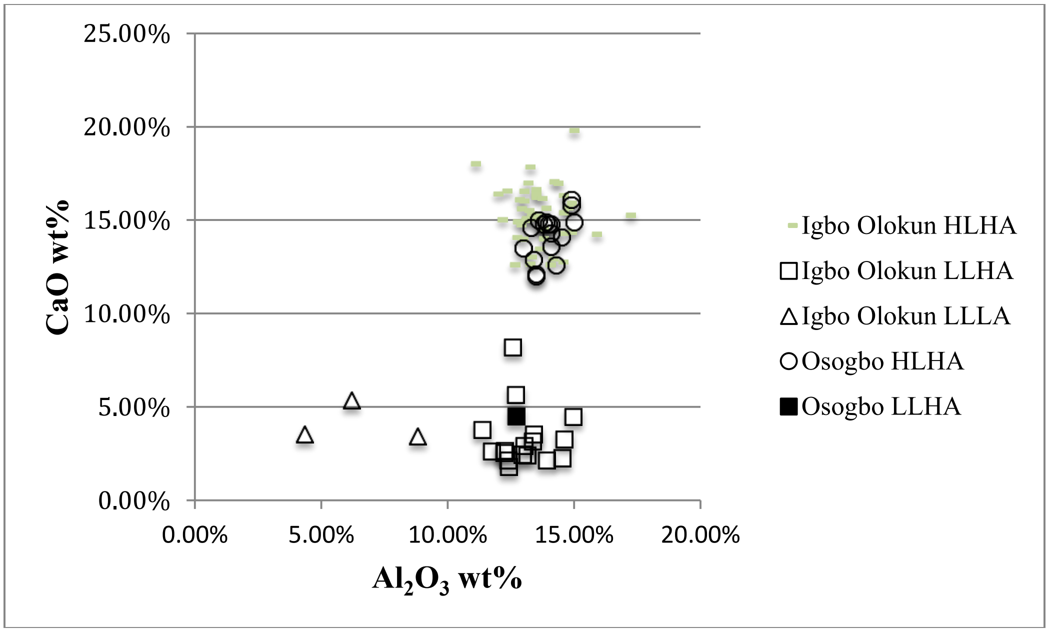


Figure 7.24: Comparison of alumina vs lime content in Ile-Ife and Osogbo glass beads, showing a very strong relationship between the two sites.

Trace element analyses by Ige *et al*. (under review) underscore the uniqueness of the Ife and Osogbo glass in terms of rubidium and strontium levels which clearly differentiate it from Mediterranean glasses. The high rubidium suggests sand derived from a granitic protolith (Ige *et al.* under review; Villaros 2009), which has been found to be common in Ile-Ife (Ige 2010b). Strontium and rubidium levels in the glass beads from Osogbo and Igbo Olokun are comparable (Fig 7.25). Ige *et al*. (under review) plotted lime levels against strontium to show a strong positive correlation, supporting their argument that snail shell was the source of both the lime and strontium in the glass. With larger sample sizes from Igbo Olokun, the correlation is present but weaker (Fig. 7.26).

The chemical compositional analysis of glass beads outside the ancient city of Ile-Ife and the comparison with Igbo Olokun assemblage has provided, for the first time, evidence of the continuity of Ile-Ife glass tradition (i.e. the HLHA and probably the LLHA glasses) in later Yoruba settlement. However, did these glass groups spread beyond the borders of Yorubaland? Or were the glass beads of these compositions involved in regional exchange and/or long-distance trade? The sections below examine the occurrence of HLHA beads in other early West African societies, as well as the possible trade routes through which Ife glass beads would have travelled to reach other communities.

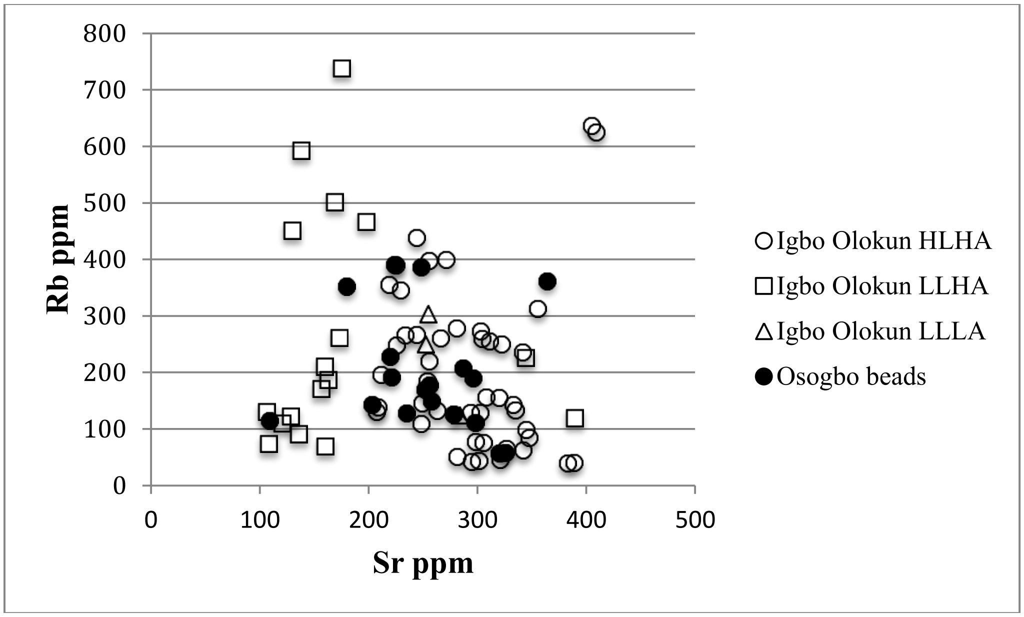


Figure 7.25: Comparison of Strontium vs Rubidium levels in Ile-Ife and Osogbo glass beads.

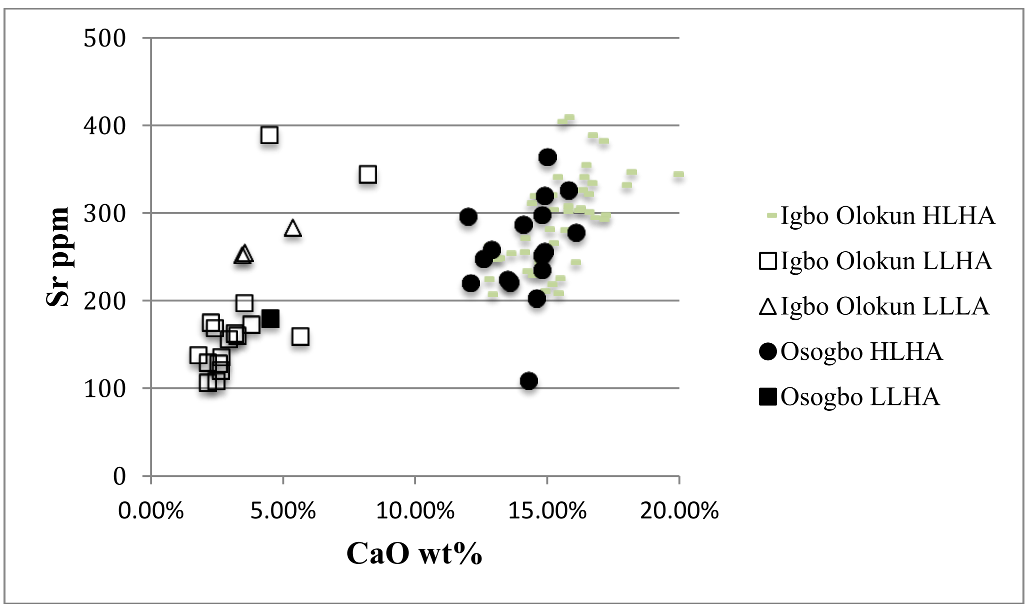


Figure 7. 26: Lime vs strontium content of Ife glass beads in comparison with Osogbo.

High Alumina Glass Beads from West African Sites

Several different glass composition groups have been identified among the Ile-Ife glass beads analyzed to date. However, at both Igbo Olokun and Osogbo, high alumina groups (with both high and low lime) overwhelmingly dominate the analyses. The distinctive recipe for high alumina glass suggests the possibility of local primary production in or around Ile-Ife (Lankton *et al*. 2006, Ige *et al*. under review), continuing as late as the 17th-18th century in Osogbo (Ige *et al*. under review ; Ogundiran 2014, Ogundiran and Ige 2015). Although glass-making may be a more widespread phenomenon in West Africa, our knowledge of early glass production is currently limited to Ile Ife, and Osogbo and, perhaps, Nupe at a later date (Ige *et al* under review; Robertshaw *et al* 2009). In view of this, I now turn to discuss the evidence for wider circulation of Ile-Ife high alumina beads, especially the HLHA group, in West Africa.

Compositional analyses of glass beads around West Africa have generated significant data that have enhanced our understanding of the sources and movement of glass beads from the late 1st millennium through 2nd millennium A.D.; this includes the movement among West African ancient societies as well as into and out of the region. (e.g., Davison 1972; Insoll and Shaw 1997; Sutton 2001; Nixon 2009; Robertshaw *et al* 2009; Cisse *et al* 2010; Cisse *et al* 2013; Robertshaw *et al* 2014). Thus far, most of the compositional groups documented from West African sites are plant ash or natron soda-lime glasses consistent with sources in the Middle East, Mediterranean, and South and Southeast Asia. Archaeological evidence and geo-chemical analysis have suggested trade from the Islamic world, and the south Asia into sub-Saharan Africa via the trans-Saharan or Indian Ocean trade networks (e.g. Nixon 2009; Wood 2011). However, high alumina beads have been found at some West African sites. Table 7.8 summarizes the compositional groups of glass beads from West African sites. Although particular high alumina glasses with possible origin in South Asia (Dussubieux *et al* 2010) or Turkey (Schibille 2011) have been identified, those from these West African sites are most consistent with Ile-Ife HLHA and sometime LLHA glass. This suggests Ile-Ife or another nearby site as the source of this valuable trade item.

vNC	mNC	vNCA	HLHA	LLHA/NAK
Soda-lime glasses			High alumina glasses	
Kissi	Kissi		Kissi	
Jenne-jeno	Jenne-jeno		Koumbi Saleh	Jenne-jeno
Gao-Saney, Gao Ancien Marandet	Gao-Saney, Gao Ancien		Ile-Ife (Ita-Yemoo, Orun Oba Ado, Igbo Olokun) Osogbo (16-18th c.)	Ile-Ife (Ita-Yemoo, Igbo Olokun), Osogbo (16-18th c.)
	Nupe (19th c.)		Elmina	
Es-Souk (8-10th c.)	Es-Souk (8-10th c.)		Gao Ancien Es-Souk	
Igbo-Ukwu	Igbo-Ukwu	Igbo-Ukwu	Igbo-Ukwu	Igbo-Ukwu

Table 7.8: Glass bead chemical compositional group for West Africa (Modified after S. McIntosh 2014). Note: vNC = Vegetable soda; mNC = Mineral soda; vNCA = Vegetable soda-alumina; NAK = Soda-potassium.

A considerable number of HLHA beads were present in Igbo-Ukwu (Davison 1972; Brill 1999), mostly among Shaw's (1970) types N3, S, and V. Of particular interest is type V, which Shaw (1970) describes as "colorless glass with a thin covering on the longitudinal surface of a reddish brown color, giving the appearance of translucent violet brown." The type occurred predominantly at Igbo Richard. HLHA beads matching this description occur at Igbo Olokun. Lankton *et al.* (2006) have done important work to synthesize the radiocarbon dates from Igbo-Ukwu and those from Ife, concluding that "the 8th to 12th century date for HLHA glass at Igbo-Ukwu supports the similar dates for HLHA glass from Ita Yemoo and Orun Oba Ado in Ile-Ife" (Lankton *et al*. 2006: 127; Willett 1977). Radiocarbon dates from Igbo Olokun suggest a chronology from the 12th century (see the discussion on the site chronology in chapter 4).

At other West African sites, HLHA glass beads have been found in first and second millennium contexts, such as at the later period of Essouk in Mali, dated to between the 10th and 12th centuries (Nixon 2009; Lankton nd). Two HLHA beads are also present at Kissi in Burkina Faso, one from Cemetery 13 with a probably date of late first millennium A.D. (Robertshaw et al. 2009). and one from Cemetery14. No definitive date is available for this cemetery, although no dated graves post-date the eleventh century (Lankton 2006:127 based on personal communication with S. Magnavita).

HLHA beads have also been found in Gao Ancien, Mali, in contexts dating between the eleventh to late fourteenth centuries (Lankton *et al*. 2006:127, based on personal communication with P. Robertshaw). Beads from earlier contexts (seventh-twelfth centuries) at Gao Saney and Gao Ancien have all been soda-lime beads (Dussubieux report in Appendix D.2, Cissé 2011). The content of lime and alumina in beads from these West African sites are comparable with those from Igbo Olokun and, by and large, other beads from Ile-Ife (Fig. 7.27). The HLHA group from other sites in West Africa is also somewhat consistent with the Igbo Olokun assemblage in terms of the content of soda and potash (Fig 7.28).

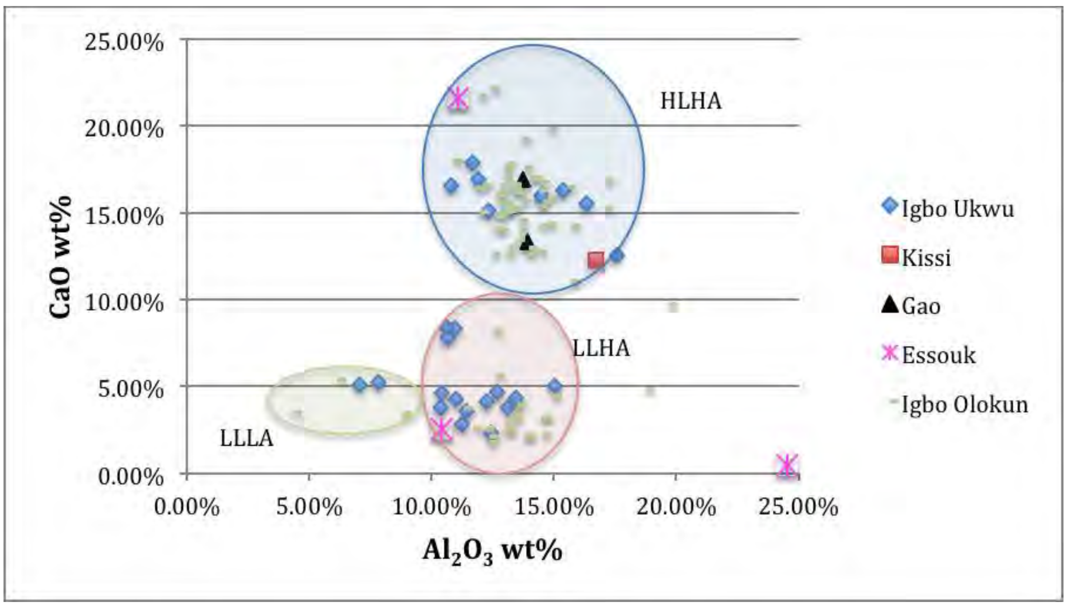


Figure 7. 27: Alumina vs Lime content of glass beads from sites around West Africa in comparison with Igbo Olokun (Ile-Ife).

The results of Principal Component Analysis (PCA) of the major elements (SiO_2, Na_2O, MgO, Al_2O_3, K_2O, and CaO) of glass beads from Igbo Olokun and other West African sites show that HLHA, LLHA, and soda-lime beads are found among the glass beads from several West African sites. These major compositional groups form clusters on the PCA chart (Fig 7.29) that strongly indicate the commonality of the groups among the West African societies during the late 1st through 2nd millennium A.D. The occurrence of HLHA glass beads in other West Africa sites, and the presence of the soda-lime glass that may have originated from the Middle East or the Mediterranean, indicate a connection between Ife and other communities during the early 2nd millennium A.D. if not earlier.

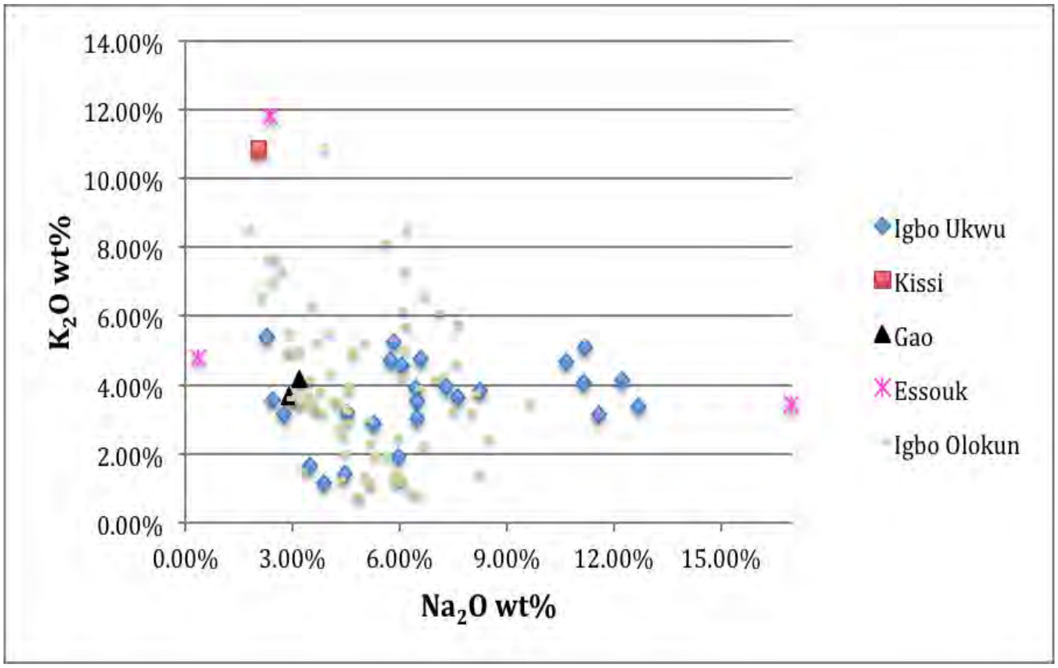


Figure 7. 28: Soda vs potash content of glass beads from sites around West Africa in comparison with Igbo Olokun (Ile-Ife).

The compositional analyses of the glass beads assemblage from Igbo Olokun have demonstrated the high frequencies of high alumina glass beads in Ile-Ife. The high alumina beads were locally produced in Ile-Ife, perhaps from late 1st millennium A.D., with evidence that the tradition continued outside the city up to the early 18th century in Yorubaland (Ogundiran 2014). This current study, along with recent works on the chemical composition of Ile-Ife glass beads, reveals the presence of Ife-type, HLHA beads further afield in other important early West African communities such as Igbo-Ukwu, Gao, Essouk, and Kissi between the late 1st and 2nd millennium A.D. Although there is need for more work on the spread of the Ile-Ife HLHA beads within West Africa and beyond, the data has built extensively on the work of Lankton *et al* (2006) to unequivocally identify Yoruba-type glass at a number of West African sites.

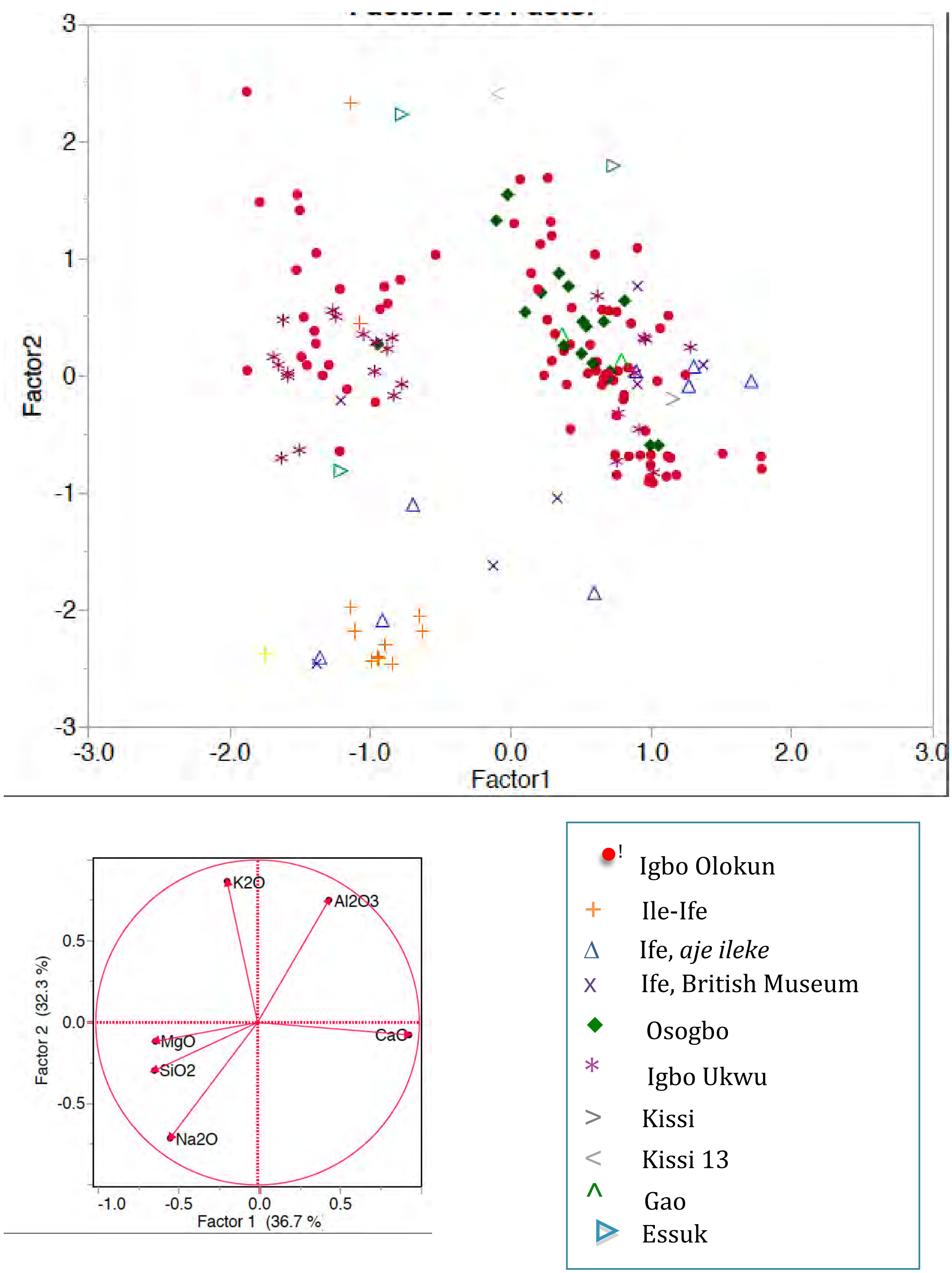


Figure 7.29. Principal Component Analysis (PCA) of glass beads from West African sites in comparison with those from Igbo Olokun. The clusters represent major composition groups.

Summary

This chapter describes the physical characteristics, and chemical compositional analysis of the glass beads recovered from Igbo Olokun. The study uses a multivariate approach that includes bead color/dichroism, shape, size, perforation, end treatment, surface condition, and manufacturing techniques and affords the opportunity for analysis of variability and patterns that are present in the assemblage. The systematic classification of such a large and diverse assemblage from a production context has no antecedent in earlier research at Ile-Ife or other West African sites. Bead-making at the site is evident in the large proportion of beads with snapped ends among the tubes and cylinders. The beads with snapped ends represent a stage in the bead-making progress. Cylinders and oblates beads were cut out of glass tubes, and perhaps, preference was given to cylinder and oblate beads over finished tubular beads.

Studies of the bead assemblage have showed blue as a preferential color; however the reason behind this preference is unknown. It is possible the abundance of blue may relate to the availability of the cobalt used for this coloration.

The chemical compositional analysis of a sample of 49 glass beads by LA-ICP-MS technique has provided us with significant data to enhance our understanding of the compositional groups of Ile-Ife glass as well as the raw materials. Although the analyzed sample is small compared to the entire assemblage, it represents the different shape, size, and color categories present. The data set is important and extremely valuable because it represents the first compositional analysis of a sample of glass beads from a reliable and well-defined archaeological context from Igbo Olokun, and by extension Ile-Ife. More importantly, the generated data are sufficient for preliminary study in order to improve on our knowledge of early Ile-Ife glass beads. However, more samples should be analyzed in the near future to represent a larger portion of the assemblage.

Results of the compositional analysis by LA-ICP-MS and SEM revealed different compositional groups. The HLHA group is the most prevalent in Ile-Ife. The high occurrence of the HLHA group in the samples analyzed for the current study corresponds with the previous studies. A relatively large proportion (50–80%) of Ile-Ife glass beads analyzed by Davison (1972) and Lankton *et al* (2006) belong to the HLHA group. This study has also identified two additional groups: LLHA and LLLA. Soda-lime group is also present at Ile-Ife, although its frequency is not well understood yet. The black beads from Ife that Brill analyzed for Ige were nearly all soda lime glass, contrasting with the low proportion in the Davison (1972) and Lankton *et al.* (2006) samples. The LLHA group possibly would have been important in Igbo Olokun, but appears to be less common than HLHA. The significance of LLLA is yet unknown. The very limited frequency of the LLLA group suggests that it represents a variant of a major group, the particular group of which cannot be presently ascertained. Because of the tiny size of all analyzed samples to date, it is impossible to know how reliably the proportions of different compositions represent the overall bead assemblage at different points in time.

Although the Igbo Olokun assemblage is generally well preserved, the occurrence of a small proportion of patinated beads were at first thought to belong to a different, maybe unidentified, group. But SEM/EDS analysis of few samples of corroded beads revealed that they belong to the HLHA group (chapter 8). Thus their corrosion appears to result from their depositional situation rather than the glass composition.

These compositional groups loosely correspond with the bead color categories. For example, HLHA are mostly shades of blue, green, clear, and occasionally white, which usually appear as stripes. Red, yellow, and sometimes white and black characterize LLHA and LLLA groups. The link between color and compositional groups could be firmly determined through the analysis of more diverse samples.

Comparison with previous work has demonstrated the preponderance of HLHA glass beads in Ile-Ife, suggesting that this glass recipe was local to the city. HLHA glass endures through time in Ile-Ife, perhaps from the 12th century and continuing through the 18th century in the Yoruba polity of Osogbo. The compositional analysis has shown that Ile-Ife engaged in regional interaction with Igbo-Ukwu through trade or exchange of the HLHA glass, and perhaps the LLHA group was also traded in much lower quantities. Although Ile-Ife HLHA glass traveled far afield within West African societies, its low occurrence in Gao and Essouk in Mali, Koumbi Saleh in Mauritania, Kissi in Burkina Faso, and Elmina in Ghana raise the question of whether or not this group was a major trade item. However, the incidence of soda-lime beads, with a probable origin in the Middle East or the Mediterranean suggests some degree of interaction between Ile-Ife and other important polities in West Africa between the late first and second millennium

A.D. Although it is difficult to determine the exact period the imported soda-lime beads started to reach Ile-Ife, their presence may suggest that at different times, various kinds of glass were being worked and used at Ile-Ife.

In order to have a deeper understanding of the techniques employed in the production of glass beads at Igbo Olokun classification and chemical compositional analysis of other production related material is essential. To address this aspect of glass working at Igbo Olokun, studies of other production related materials found at Igbo Olokun are presented in the next chapter.

Chapter Eight
PRODUCTION RELATED MATERIALS

Introduction

Numerous materials relating to glass production were recovered from our excavations at Ile-Ife. These materials include crucible fragments, vitrified production debris (VPD), glass wasters, and ceramic cylinders. This chapter presents analysis of these materials. The analysis is in two parts: the first part provides an overview and description of the materials from excavated units; the second part the results of chemical composition analysis that was carried out on selected samples from each category of the production materials. This analysis was done through LA-ICP-MS and a scanning electron microscope (SEM) with an energy dispersive spectrometer (EDS) conducted at UCL Qatar's Archaeological Materials Science Laboratories, with funding from Qatar Foundation. The questions of interest in this study focus on the kind of processing activities these materials represent. Was primary production of glass carried out, as Lankton *et al* (2006) have proposed for the high-alumina glass beads? Or was secondary production (remelting and bead-making) occurring, as Willet (1977) and Davison (1972) suggested? The analysis of glass beads from various sites and contexts in Ife has shown that a variety of compositions are present - high lime, high alumina; low lime, high alumina; plant ash, and small numbers of other types (Chapter 7). Now we ask which of these groups is present in the production materials and what activities were the Igbo Olokun glass craftsmen undertaking?

Studies on glass production in ancient West Africa are very limited due to the paucity of convincing and substantial evidence of such activities in the past (see chapter 3). Far more production sites are known and documented in Egypt and the Middle East at large. Most of the glass found in first and second millennium contexts in West Africa has furnished us with information on consumption patterns and trade rather than primary production. In the few cases where there is evidence of some form of production, it concerns either the historic period and/or secondary reworking of glass (e.g. DeCorse 2001; Cisse 2011).

Lankton *et al* (2006) have argued that primary glass production was carried out in or around Ile-Ife in southern Nigeria in the early second millennium A.D. The recovery of production materials from known excavated contexts in the research described here presents an opportunity to evaluate the evidence for primary glass production in greater detail through analysis of the various categories of production debris. Although my argument here complements that of Lankton *et al* (2006) that Ife's high lime, high alumina (HLHA) was produced locally, I provide more nuanced archaeological context to the discussion on primary glass production in Ile-Ife through a thorough analysis of the production debris, beginning with physical description of the categories of debris recovered. The results of various analyses on these materials will then be presented.

Crucibles

The 2011/2012 excavations at Igbo Olokun recovered 871 crucible fragments from all the units. The substantial number of crucible fragments offers important data concerning ancient glass production in early Ile-Ife. First, I discuss recovery and recording methods, including the variables considered in analysis. Then, I present the analysis of the crucibles and an overview of the assemblage from the excavated units.

Recovery and Recording Procedure

During the excavations we recovered crucibles both by hand from the units and in the screens. All the excavated crucible fragments were bagged separately from other artifacts with the provenance information written on the bags. All fragments from each level and units were washed, dried, repacked in their respective plastic bags and subsequently counted, weighed, and measured. While sorting, attention was paid to fragments that may belong to the same vessel. This was determined by the color of glass encrustation on the inside of the crucibles, and the thickness and fabric of the crucibles. Multiple fragments of the same vessel were recorded together as a single crucible. All other crucible fragments were individually recorded, with the exception of small fragments less than 4 cm across. We only counted and noted the characteristics of crucible fragments that are less than 4cm across (Appendix E.1).

The variables recorded on the large crucible fragments include the provenance (unit and level), thickness (measured with calipers), vessel part (rim, base, body), presence or absence and color of glass encrustation on both the inside and the outside, paste color, and weight. The variables and the codes used for the recording are presented in Table 8.1.

Weight (Determined on scale)	**Thickness** (Measured with calipers)	**Part** Rim = 1 Body = 2 Base = 3
Inside Glass (IG) Presence = 1 Absence = 2	**Outside Glass (OI)** Presence = 1 Absence = 2	**Glass Color Inside (GCI)** None = 0 Blue = 1 Green = 2 Red = 3 Blue-green = 4 Black = 5 White (Corroded) = 6 Polychrome = 7
Glass Color Outside (Same as GCI)	**Inside Surface** Smooth = 1 Rough/Striations = 2	**Outside SURFACE** Smooth = 1 Rough = 2
Paste Color White = 1 Others (Dark & Light gray)= 2		

Table 8.1: Summary of the variables and codes used for recording crucibles

Overview Description of the assemblage

Of the total of 871 crucible fragments (weighing over 40 kilograms) recovered from the excavations, 365 were less than 4 cm across and not included in the quantitative analysis. Also the 54 crucible fragments earlier reported from the 2010 test excavation were excluded (Babalola 2011). The variables mentioned above were recorded for each of the 506 crucible fragments studied. Table 8.2 provides the frequency distributions of crucibles by levels in the excavation units. Crucibles are concentrated in units IO-B, C, and D, and 2010 test unit TP1, but with highest density of $496/m^3$ in the entire unit IO-B/D.[1] Crucibles are rare in unit OO-A and absent in TP2 at Igbo Rudi, indicating show that these areas are not associated with the glass industry (See figure 4.3 for the location of the units).

Levels	IO-A	IO-B	IO-C	IO-D	IO-E	OO-A	Total
1	14	3	8	8	8		41
2	4	6	19	39	31	1	100
3	25	3	18	25	15		86
4	4	57	55	35			151
5		27	74	30			131
6		29	73	106			208
7		35	17	48		4	104
8		50					50
Total	47	210	264	291	54	5	871

Table 8.2: Frequency distribution of crucibles fragments from excavation units by levels

Crucible morphology

Rim, body, base, and lid fragments were recognized in the assemblage (Fig. 8.1 A-G). Table 8.3 presents the frequency distribution of crucible vessel parts. Body fragments constitute over 80% of the assemblage across the units, while bases were less than 1%. Glass fusion on the interior of the crucible fragments is an important characteristic of body fragments.

Rim frequencies averaged about 10% across the units. In general, we could not determine the diameters of rim fragments because of their small size. However, a single larger fragment in the assemblage provided a 7.8cm diameter (Fig. 8.1C). This diameter

1 See chapter 4 for discussion on why excavation units IO-B and D were combined

does not suggest an average diameter for the vessels in the assemblage. Most of the rims are simple with rounded lips. Occasionally, a flattened surface is noticed on the lip of the rim. This surface may represent wear resulting from contact with a lid, or a platform deliberately formed for the lid. Close observation of the rims in our collection and the complete crucible vessels on display both at the Ile-Ife and the British Museum shows that vessels in the assemblage have a restricted orifice, ranging from slightly closed (about 45^0) to closed (almost 90^0). The crucible vessels appear to have been ovoid or elongated-ovoid with a flat base (Fig. 8.1 A –F), corresponding to the form illustrated by Willet (2004).

Lids may have been common accessory, but they are not well represented in the assemblage. The only recognizable lid fragment came from level 7 of unit B/D in pit II, and is hemispherical in shape. There are two holes with diameters of 2–3 cm on the side of the fragment. These holes appear to have been a set of possibly three (Fig. 8.1G, Fig 8.2) into which rods would have been inserted to lift the lid. There is glass fusion on the ventral side of the lid. The glass encrustation in the under side of the lid is restricted to the outer circumference of the surface in different layers (Fig. 8.1G). The size of the lid and its overall morphology is different from those known in archaeological literature of Ile-Ife.

The fragmentary nature of the assemblage made it difficult to estimate the number of vessels represented in the assemblage. However, since none of the 36 rims seems to belong to the same vessel, we can assume that this represents the minimum number of crucibles in the assemblage (Table 8.3).

Units	Rim	Body	Base	< 4cm	Total
IO-A	3	34		10	47
IO-B	9	105	1	95	210
IO-C	12	158		94	264
IO-D	10	141	4	136	291
IO-E	2	19		33	54
OO-A		2		3	5
Total	36	459	5	371	871

Table 8.3: Frequency distribution of vessel parts of the crucibles recorded by units

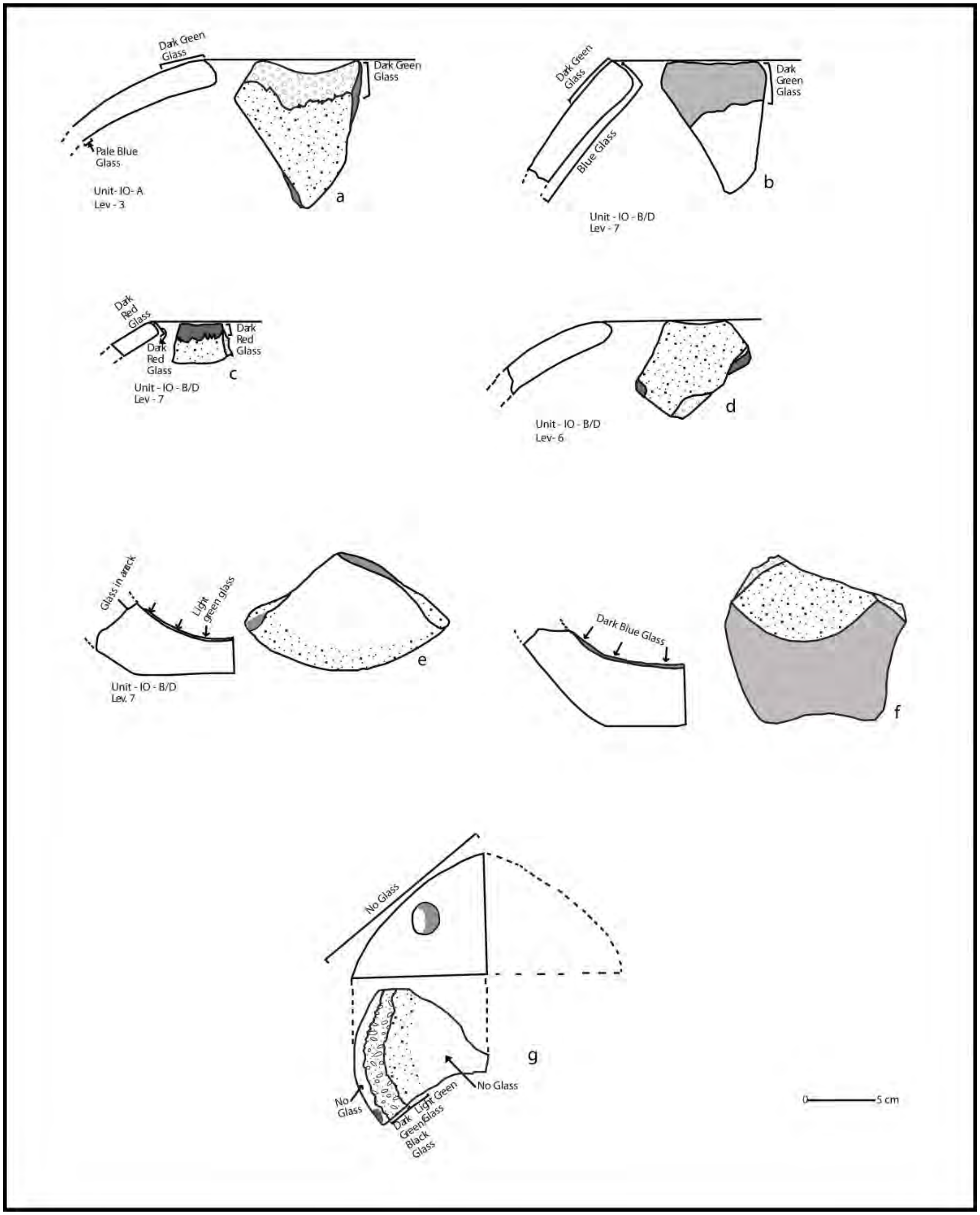


Figure 8.1: Ile-Ife Crucible Profile (Base A, B; Rim C, D, E, F; Lid G).

Figure 8.2: Crucible lid from Igbo Olokun. Note the probable rod hole

Crucible fabric, inner glass and outer glaze. Visual examination of fresh breaks on the crucibles reveals that the fabric color varies from dark and light gray to white (Munsell values 2.5Y 6/1, 7/1, 8/1 and 5Y 7/1, 8/1). Occasionally the fabric color is off-white with light yellowish tone (Munsell value 2.5Y 8/2 and 5Y 8/2). About two-thirds of the fragments have a smooth, well-preserved layer of melted glass on their interior surfaces. The thickness of the inner glass varies from less than 1mm (thin layer) to 10mm (thick layer) (Fig. 8.3). Sometimes, striations were noticed on the crucibles' interior, which created bumps or ridges on the interior surface. These striations formed either multidirectional or unidirectional patterns (Fig. 8.4). Willett (2004) has suggested that these ridges reveal that glass melt was scooped out of the crucible. The absence of ridges on the inner glass of some of the crucible fragments indicates that other method was also used to gather the glass melt from inside the crucible. It may be that glass melt was scooped out of some crucibles, yet the condition that determines which method to use in gathering glass melt from crucible remains unknown. Approximately one-third of the assemblage does not have glass in the interior. The absence of glass on the inside of some of the crucibles suggests a number of possibilities. First, the crucibles without glass in the interior may not have been used in glass melting; this seems unlikely, however, as crucibles were specialized vessels produced for a particular function. Some may have broken before they could be used, however. Or, it is possible that they were used in glass melting, but the glass layer has flaked away through a natural depositional process. In this regards, occasionally, there is a trace of glass that had chipped off the crucible. Third, the crucible fragments in this category could have come from parts of crucible vessels closer to the rim and above the "glass level" (Pusch and Rehren 2007: 134). These possibilities need to be evaluated as further studies are carried out on the assemblage.

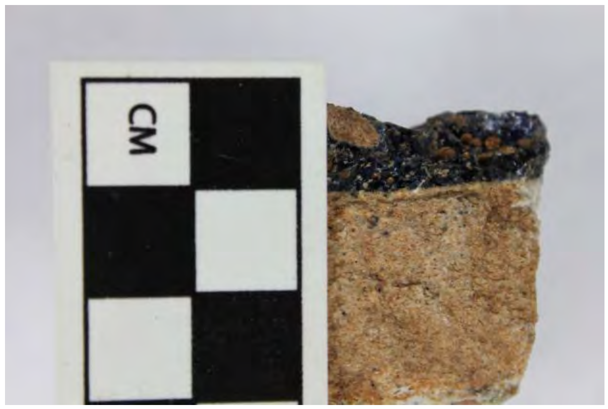


Figure 8.3: Example of thick glass fused on the crucible interior

Figure 8.4: Crucible fragments with ridges/striations on the interior glass

About 40% of the assemblage has ridges of glaze, and vitrified glassy material on the exterior surface. This may be the result of spilling melted glass on the outer body of the crucible vessel while production was in progress, or a reaction between the vessel clay and the fuel ash resulting from intense high-temperature heating.

The glass color categories are the same as for the glass beads (Table 7.1; Appendix E.2), except yellow glass is absent and a blue-green category was created for the crucibles. Among the basic colors identified, as shown in figure 8.5, blue and green are the most common. Other colors present in low frequencies are red, blue-green, and black. Occasionally, two colors or shades of the same color were observed on a single crucible fragment (Fig. 8.6). This could have resulted from variations in chemical concentration due to poor mixing of the colorants (see detail below in the analysis of chemical signature of various samples). It could also suggest that the crucible was used multiple times for different color batches (Willett 2004). Results of the chemical analysis shed light on this.

The thickness of the crucibles varies considerably among different vessel parts. Overall thickness of between 2 and 2.9 cm is the most common for body walls (Fig. 8.7). Although there are fewer bases, they seem to generally have greater thickness.

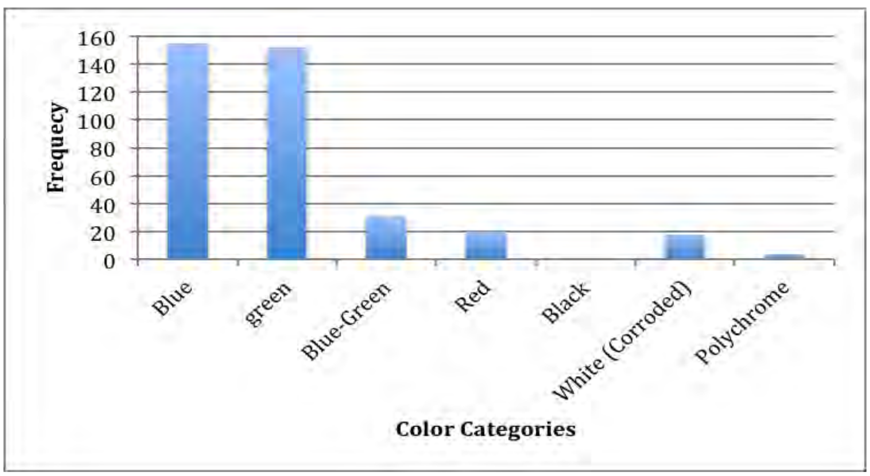


Figure 8.5: Frequency of glass color categories on the interior surface of crucibles

Figure 8.6: Example of crucibles with multi-color glass on the inside

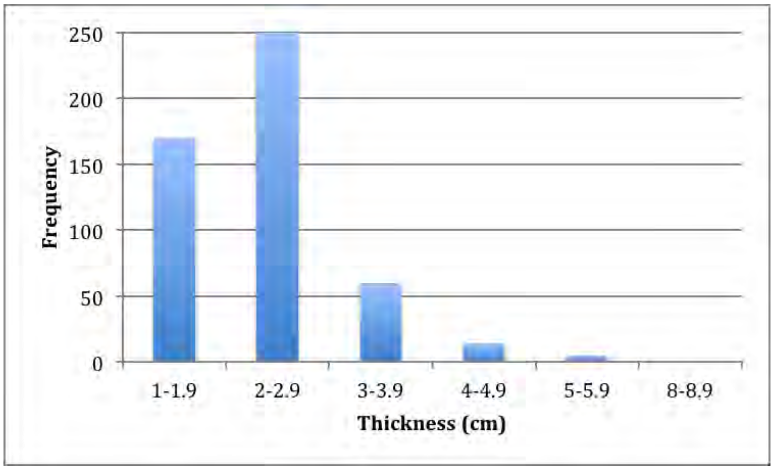


Figure 8. 7: Thickness distribution of Ile-Ife crucibles

Vitrified Production Debris (VPD)

During our 2010 preliminary excavation at Igbo Olokun we encountered vitrified production debris (VPD) but did not recognize it as such; its resemblance to stones or 'metamorphic' sandstone caused us to treat it as natural geological material rather than cultural material. During the 2011/2012 excavations, we still did not recognize it as anthropogenic, but we noted its presence or absence from each unit in field notes. We collected a few samples randomly across the units for identification and further analysis, especially chemical analysis, to determine elemental characteristics.

VPD occurred in high frequencies weighing approximately 30 kilograms in four excavations units at Igbo Olokun (A, B, C, and D), and in low frequencies in two levels in unit E; it is completely absent from unit OO-A. VPD appears in amorphous shapes with lots of bubble voids (Fig. 8.8). Some times a portion of almost regular shiny surface is identifiable. Close examination of fresh breaks on samples of the VPD revealed that the main constituent is vitrified former clay with quartz grain inclusions, ranging from fine to coarse. VPD are either highly vitrified or semi-vitrified. The paste is mostly shiny, which suggests vitrification. As a single piece of VPD can be both highly vitrified and semi-vitrified in different parts, it can also have fine and coarse quartz grains. This characteristic may demonstrate the degree to which the material was subjected to heat, as well as the mixing proportions of clay and quartz. Sometimes, whitish glaze-like layers occurred on the outer surface or sandwiched in the matrix of the material (Fig. 8.8).

The recognition and analysis of VPD from our excavations provides new insight on craft production in Ile-Ife. No other site had recognized such material in and around Yorubaland. The closest account of material that may resemble VPD is in Eluyemi's report of his investigation at Olokun grove (Igbo Olokun) where he states iron slag among the materials recovered from his excavations at the grove (Eluyemi 1987: 197, 200

A few samples of VPD were selected for chemical and mineralogical analysis to better understand their nature, the process that produced them, and their use.

Figure 8.8: Vitrified Production Debris (VPD) from Ile-Ife. Arrow pointing at the sandwiched whitish/grayish substance

Ceramic Cylinders

A large number of ceramic cylinders/pottery rods were recovered from the excavated units. The systematic analysis of these objects was aimed toward revealing whether they were used in some form of production. Here I discuss the method of recovery and recording of this class of artifact, describe the variables recorded, and briefly present an overview of the material.

Ceramic cylinders were recovered in excavations and from the screen. Any concentration was recorded in our field notes, drawn and photographed. After we washed and dried the materials, they were counted and weighed; their attributes were recorded individually in Excel spreadsheet (Appendix E.3). We did not record those that are badly fragmented without complete circumference. Instead, we only counted the fragmented ones and noted their count in the comment column of the spreadsheet. Similarly, those that seem to have come from the same piece were identified and recorded as a single piece. On each of the diagnostic ceramic cylinder, we recorded variables such as the thickness, which represents the diameter, weight, endform, surface condition, oxidization, and paste (Appendix E.3).

The analysis has revealed some characteristics of the material that may help not only in detailing the distribution and description, but also strengthening our interpretative power. A total of 205 fragments of ceramic cylinder were analyzed, all of which came from units IO-A through D within the Igbo Olokun “core area”. As was the case in 2010 (Babalola 2011), no complete cylinders were recovered from the 2011-2012 excavations. However thorough examination of this category of finds helps to determine some of the characteristics. The ceramic cylinders have at least three parts as represented in the assemblage: tip, shaft, and base (Fig. 8.9). While the tips are tapered, the bases are possibly flat. Occasionally, a form of dimple was noticed in the flat surface of some of the bases, which may indicate that they were formed by pinching and tucking the clay. The diameter of the object varies from 1 to 3 cm with majority between 1.5 and 2.5 cm. Ceramic cylinders with diameter above 2.5 cm are rare in the assemblage.

The most striking feature of the ceramic cylinders is the encrustation of a substance on the surface (Fig. 8. 9) on over 90% of the assemblage. This coating suggests that they had been used in high temperature activity. The color of the coating ranges between off-white and dark gray. The coating covers only half of the circumference, although rarely it does appear on the entire material. In the case it covers the entire material, it is usually restricted to the basal section of the cylinder. Examination of fresh breaks on the samples shows that the paste color varies from orange to very dark gray or black. The orange color of the paste suggests that they were well fired or used consistently in firing processes.

Within Yorubaland, this category of artifact has not previously been described, although Eluyemi (1987) mentioned pottery “plugs” among his finds at Igbo Olokun.

While he did not describe the material in detail, I believe he must be referring to the ceramic cylinders. Since these artifacts appear to fit into the hole in the crucible lid identified at Igbo Olokun, Willett suggests that they may have been handles used in removing the crucible lid (Willett 2004). This line of interpretation was supported initially (Babalola 2012). Current analysis as discussed later shows that it is unlikely that the ceramic cylinder would support the weight of the crucible lid. In addition, Willett (2004, T840 comment) describes the ceramic cylinders as being covered with glass. Willett was likely referring to the encrustation on the artifacts as glass. However, the results (see below) of chemical compositional analysis suggests otherwise. The compositional analysis has also helped to answer questions pertaining to the use of the ceramic cylinder and their association with glass making and/or glass working in Igbo Olokun.

Figure 8.9: Fragments of ceramic cylinders from Ile-Ife. [Note: top – left, tips; right, bases (note the heavy encrustation); middle – left and right, shafts (note the minimal encrustation); bottom, more shafts but bigger in size]

Glass Debris/Wasters

Three kilograms of glass debris were recovered from the excavations primarily in units B-D and C. While units B-D produced the majority by weight, the density of glass debris was greatest in unit C. Glass debris was rare in unit OO-A. The rarity of debris in unit OO-A may be attributed to the reasons already discussed in Chapter 4.

Examination of the mass of glass debris revealed various debris categories. These categories include different stages of production activities at the site: glass production, tube drawing, and bead making. For the debris categories (Table 8.4), Peter Francis' (2004) extensive work on glass beads from Arikamadu was useful; this study details Indo-Pacific bead making processes and the associated debris. I have modified some of Francis' categories to better describe the assemblage from Ile-Ife. This categorization is important in reconstructing the technique and process of glassmaking and glass working at the site, since the examination of the wasters can help reconstruct the mode of production (Francis 2004: 451). Vessel glass is completely absent from the assemblage, indicating that imported cullet was not being re-melted in the glass bead production process, an observation that has been made by Lankton *et al* (2006) and Ige *et al* (under review).

In view of the large amount of glass wasters recovered from the excavation, a sampling strategy was adopted for the analysis. Since units B, C, and D had the highest concentration, 25% of the debris assemblage was taken from the most productive level in each of these units for recording. Thus, 25% of the debris from levels 4, 6, and 5 in units B, C, and D respectively were analyzed. All fused beads were recorded, since they could be easily identified by the clumps they formed within the debris assemblage. Since the result of the test recording did not show any significant difference among the units, I based my analysis here, except otherwise stated, on the 25% sample from the aforementioned levels and units. In total, 3,396 debris elements and 341 fused beads were analyzed (Appendix E.4; Table 8.5).

Production Stages	Debris Categories	Description
Glass Debris	Flakes (FK)	Angular, but flat glass pieces; in general term these are cullet
	Chunks (CK)	More rounded and thicker than flakes
	Glass droplets (drips) (GD):	Droplets of melted glass; when solidify it forms a well rounded shape, at times with the tip of the dropping
	Fragments with crucible (FC)	Glass fragments with part of crucible attached to them
	Porous droplets (PD):	Tan, with evidence of air bubbles, mostly degraded droplets
	Glass/glass bead fragments (GGF)	Unclassifiable fragments
Tube Drawing	Unperforated cane (UC):	Drawn glass cane with no evidence of perforation
	Amorphous pulled shape (AS):	Tube fragments with irregular shapes
	Flattened tube (FT):	Tubes with signs of perforation but flattened
	Collapsed cane (CC):	Canes without a hole, from end
	Flared tube (FDT):	Tubes with a flared end; must have formed the end of a tube
	Broken tube fragment (BTF)	All qualities of a tube, but broken either by natural or human agents
Bead making	Miscut bead (MB):	has shape of bead, but was miscut from tube, which leaves it with a very thin crescent shape
	Fused or clump (CP):	groups of beads melted together
	Malformed (MF):	overheated beads

Table 8.4: Description of the identified glass production debris categories

	Fused Beads						
Units	Blue	Clear	Green	Red/Clear	Stripe	Yellow	Total
IO-B	79	2	0	1	2	3	87
IO-C	128	8	11	3	0	0	150
IO-D	98	1	1	1	0	2	103
IO-E	1	0	0	0	0	0	1
OO-A	0	0	0	0	0	0	0
Total	**306**	**11**	**12**	**5**	**2**	**5**	**341**

Table 8.5: Distribution of fused glass beads from Ile-Ife by color.

In this chapter, I will evaluate the evidence from the waste debris for both local primary glass production and glass bead making at Igbo Olokun. Lankton et al. (2006) and Freestone (2006) have presented strong arguments for primary glass production of indigenous derivation in southwest Nigeria. Was Igbo Olokun a site where glass was made? The hypothesis of primary glass production will be investigated along with any evidence for imported glass. Chemical analysis is our most useful tool for these studies.

Chemical Analysis of Glass Production-Related Materials

Introduction

This section essentially reports the results of SEM-EDS analysis of selected materials from our archaeological excavations at Igbo Olokun, carried out at the Archaeological Material Science Laboratory at UCL Qatar, and overseen by Prof. Thilo Rehren. The materials selected for the analysis include ten crucibles fragments, three ceramic cylinders, three glass droplets, three glass beads, and five samples of VPD. In addition, seven sherds of domestic pottery were analyzed for comparative purposes.

The aims of this study were to carry out analytic examination on the above-mentioned materials in order to understand technical and functional aspects of Ile-Ife crucibles and investigate the process of production of glass making and working in Ife. I first describe the methods used in the preparation of the samples for analysis. I then discuss results of the SEM analysis of microstructure and the EDS analysis of chemical composition for each of the materials studied. This is followed by a brief presentation of the result of LA-ICP-MS analysis carried out on additional production-related materials. Finally, I discuss the functional and production related issues that are indicated by the analysis.

Methods

Small fragments of the samples were cut and mounted in epoxy resin, and polished. In the case of crucibles, two small pieces were mounted in each resin block, one each presenting a cross-section showing an outer, glassy or sintered coating, the crucible fabric, and a glass layer on the interior (Appendix E.5). The samples were carbon coated before been mounted for analysis. Each sample was studied by optical microscope and scanning electron microscope (SEM) for microstructural analysis. Additionally, the chemical composition was analyzed through Energy Dispersive Spectrometry (EDS) of two or more areas within a specific segment of each sample. Occasionally, spot analysis was done on crystalline phases noticed in the sample. The results were then organized by segment for easy comparison of the composition.

The methods used for the LA-ICP-MS techniques are discussed in Appendix D.2.

Crucibles

Ten crucible samples were selected for detailed analysis with the SEM-EDS (Appendix E.5). Eight of the crucible samples came from contexts of potentially variable dates in the 2011 and 2012 excavations. In addition, two surface samples collected by Professor Ige of the Natural History Museum, Obafemi Awolowo University, Ile-Ife were analyzed to help establish whether material on the surface is similar to material from archaeological deposits. Appendix E.6 provides detailed provenience information and description of the analyzed crucible samples.

The focus of the analysis of the crucibles targeted five different segments: the outer glassy coating, outer crucible fabric, inner crucible fabric, interior glass layer, and the transition between the latter two. These segments were selected for analysis in order to see if there were any recognizable differences in the microstructure and composition among the crucible fragments. The interior transition area was examined for evidence of the interaction of the glass with the fabric; this provides a check for the degree of leaching of chemical composition from the crucible fabric into the glass and vice versa. Appendix E. 7 presents the result of all the areas and spots chemically analyzed by SEM-EDS in all the crucible samples.

SEM Analysis of Microstructure

Outer glassy coating. Determining the nature of the outer coating, whether it was the result of fuel ash or glass proper, was a major objective of the analysis. Examination of the microstructure of the outer coating has shown a distinction between the outer coating and the crucible fabric, with greater vitrification of the outer coating (Fig. 8.10). In cases where the outer crucible fabric is highly vitrified, the distinction is less clear (Fig. 8.11). In most instances, the coating appears homogeneous, occasionally with a corroded surface resulting from chemical interaction in the soil (Fig. 8.12).

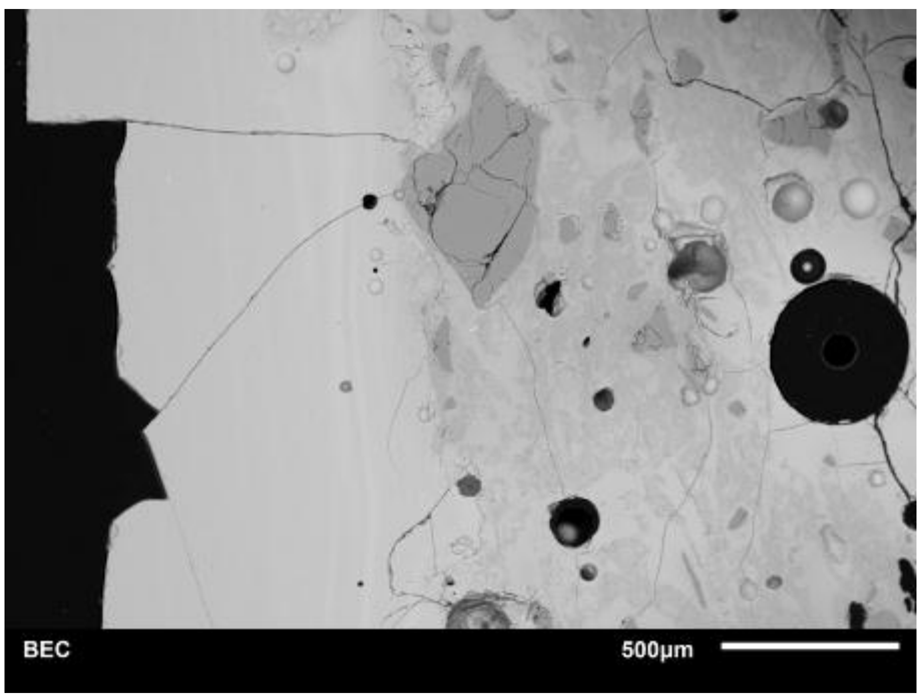


Figure 8.10. Back-scatter SEM image of outer glassy coating.

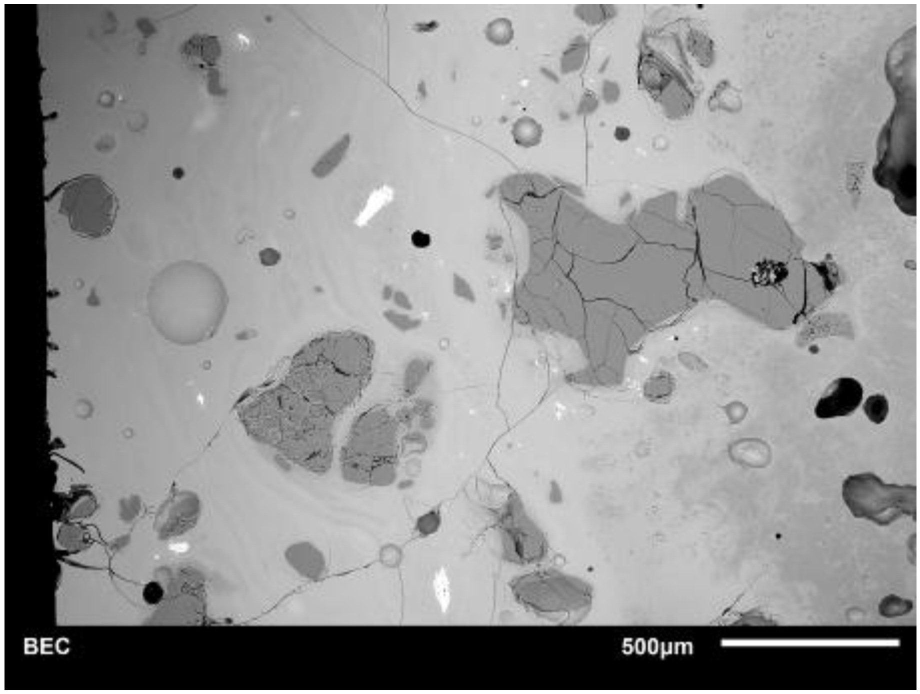


Figure 8.11. Back-scatter SEM image of outer glassy coating showing high degree of vitrification.

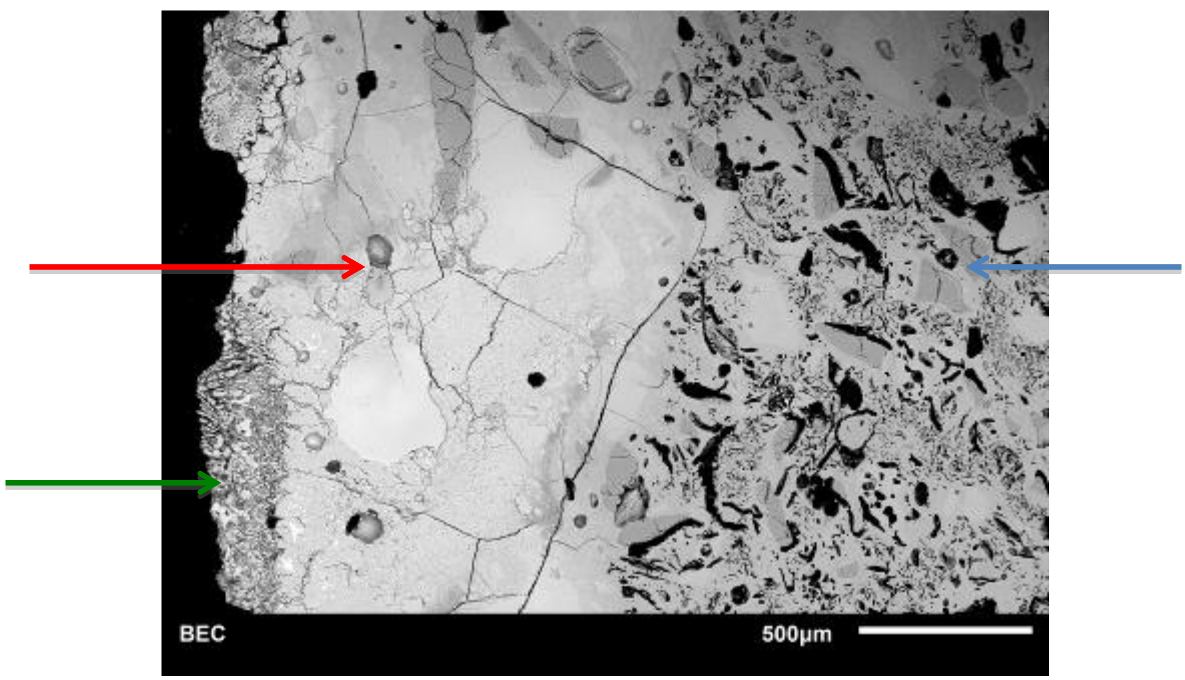


Figure 8.12. Back-scatter SEM image of outer glassy coating showing outer corrosion to the left (green arrow, bottom left), and the difference between the degree of vitrification of the outer (red arrow, top left) and inner (blue arrow, right) fabric.

Although not very clear from the SEM, swirl-like structures appear in a few samples. This pattern is also visually noticeable in the samples (Appendix E.5, sample IF0073), which appear in dark and light blue. Although a swirled appearance in glass microstructure may be evidence of improper mixing of the colorant in a glass batch, the occurrence in the outer glassy coating is difficult to ascribe to improper mixing.

Crucible Fabric. Visual examination under the optical and backscatter electron microscopes revealed a simple microstructure. Quartz grains appear as a common constituent of the fabric (Fig. 8.13):

> "the quartz grains are firmly embedded in a highly vitrified matrix of glass, newly-formed mullite, and some other accessory minerals. Most of the quartz grains show thermal fracturing, due to their being stuck to the vitrified matrix when shrinking back to their smaller crystal size when transitioning down below 610 °C" (Rehren, personal communication, 2013)

In addition, the fabric appears highly vitrified, with greater vitrification and correspondingly less complex microstructure in the outer fabric compared to the inner fabric (Figs. 8.14 & 8.15). Both elongated and circular voids were observed in the inner fabric or less vitrified area (Fig. 8.15). While the elongated voids may indicate the former presence of organic materials, the circular voids may represent natural spaces in the clay matrix. It is uncertain whether the organic materials as well as the quartz grains were intentionally added to the clay as temper or not. However, based on the volume, rounded nature, and the consistent size of the quartz grains in the Ile-Ife crucibles, Lankton *et al*. (2006: 119) have suggested that they are more likely to be natural sand components in the crucible clay.

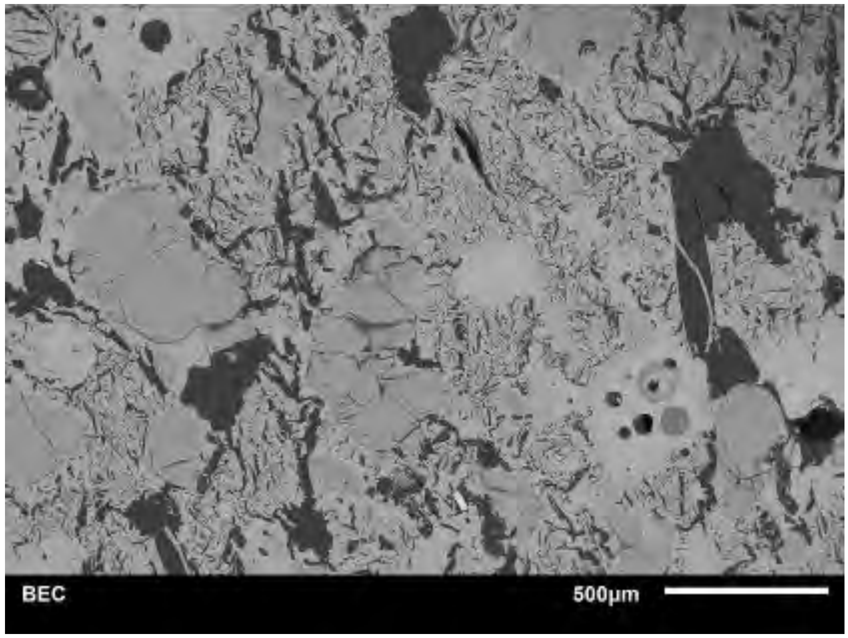


Figure 8.13. Backscatter SEM image of the fabric of Ile-Ife crucible showing thermal fracture of the quartz grains in the matrix.

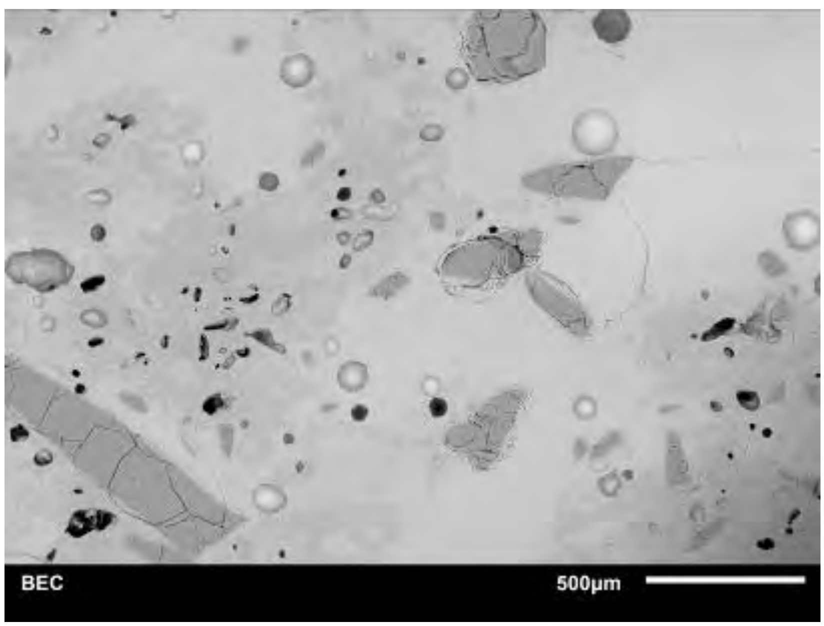


Figure 8.14. Backscatter SEM image of the heavily vitrified outer crucible fabric.

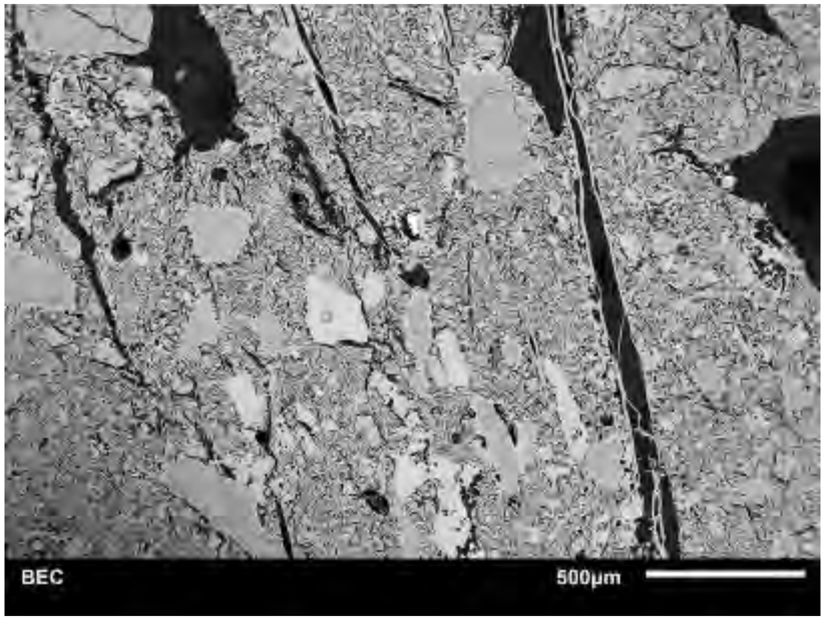


Figure 8.15. Backscatter SEM image of the inner crucible fabric with burnt-out organic fibers.

Inner glass. The interior glass samples are mostly homogeneous with no microstructure. Figure 8.16 represents an example of backscatter SEM image of homogeneous glass. However, occasionally, unmelted quartz grains and swirls or ocean-wave-like structures are present in the inner glass matrix (Fig. 8.17). These quartz grains and the swirls may have implications for understanding glass making and some of the functions of the crucibles. Alternatively, these could be due to the partial absorption of the ceramic into the glass melt. Although the explanations for the presence of the quartz grains in the inner glass matrix needs further close examination, a preliminary suggestion is provided below.

Glass in the inner transition zone. The transition zone refers to the area where the crucible fabric and the inner glass make contact. Glass immediately fronting this zone was examined under high magnification with the SEM. The microstructure of glass in the transition zone is, in most cases, similar to the interior glass: it appears homogeneous under high magnification but heterogeneous under low magnification. This means that low magnification helped to view the surrounding areas while high magnification made it look homogeneous. Either way, glass in the transition zone is mostly characterized by darker shades of gray (Fig. 8.18). These darker shades of gray appear in layers or as crystals. It is not certain whether the occurrence of the different shades of gray in the transition resulted from the interaction of elements in the zone or if they are evidence of some process in the production. Some white needle-like crystals were also noticed in the transition.

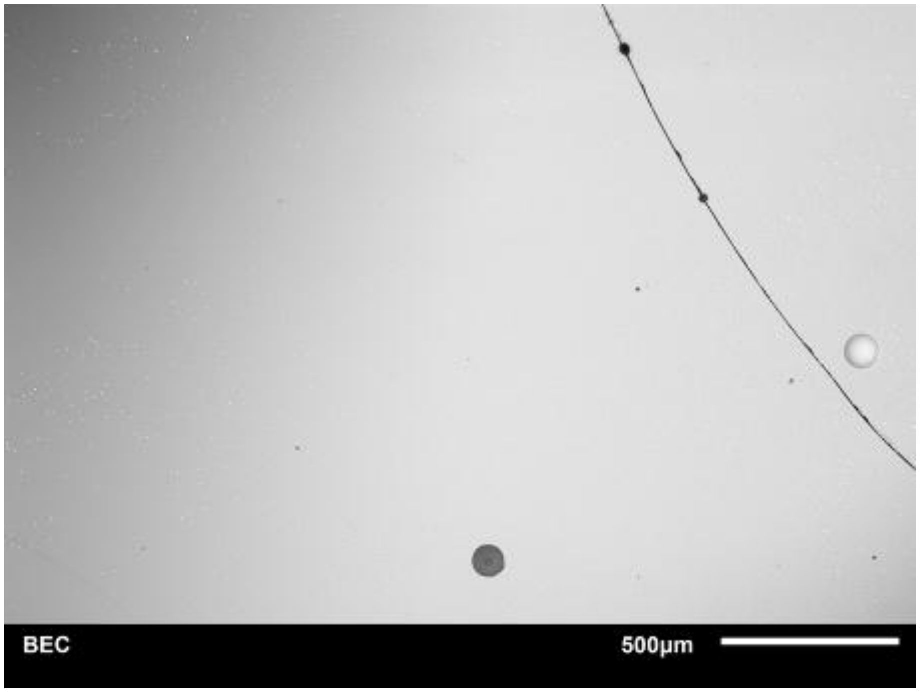


Figure 8.16. Backscatter SEM image of typical Ile-Ife glass matrix.

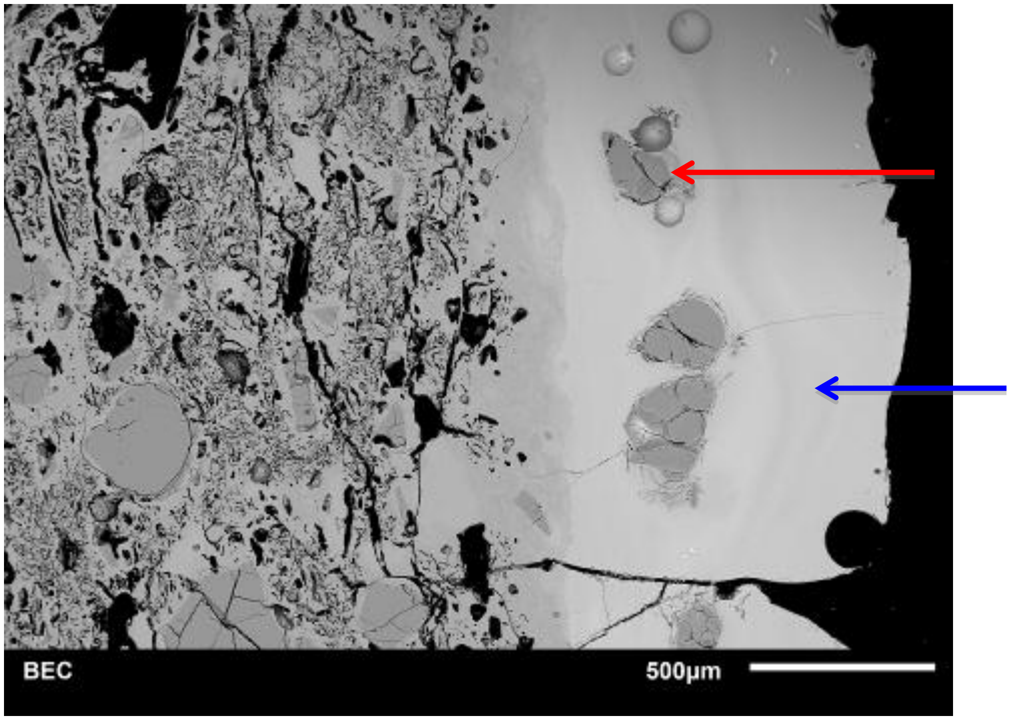


Figure 8.17. Backscatter SEM image of inner glass, showing the quartz grains in the matrix of the inner glass (red arrow, top), and the different shades of gray in swirls and/or ocean wave-like patterns (blue arrow, bottom).

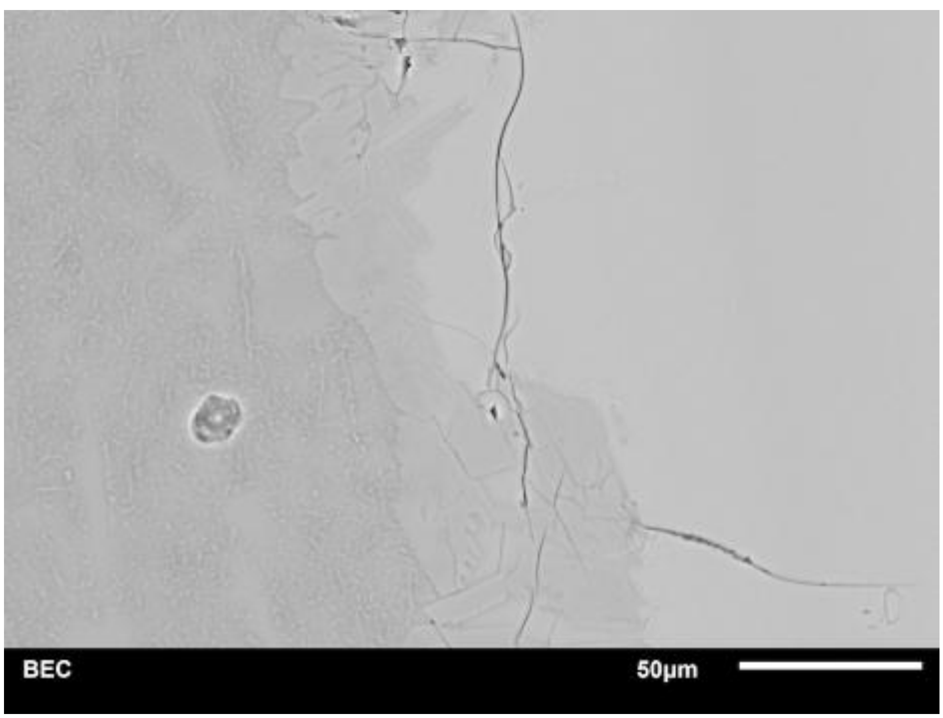


Figure 8.18: Backscatter SEM close-up image of the glass in the transition zone.

EDS Analysis of Chemical Composition

Outer glassy coating. Results of the EDS analysis of chemical composition show that the outer glassy coating is characterized by high lime (10–30%) and high alumina (10–20%), referred to here as 'HLHA.' (Fig. 8.19, Table 8.6). Soda concentration is generally low in the samples, mostly below 1.0%, however, samples IF0074 and IF0075 have elevated Na_2O. The elevated soda in these two HLHA samples may be related to glass contamination or spillage on the outer portion of the crucible. However, the elevated concentrations of oxides of magnesium (MgO), phosphorus (P_2O_5), and potassium (K_2O) in the outer coating samples are not found in the glass samples, which suggest that the outer coating is a substance other than the inner glass. Other oxides vary: titanium oxide (TiO_2) is 1–3% in over half of the samples, and iron oxide varies widely.

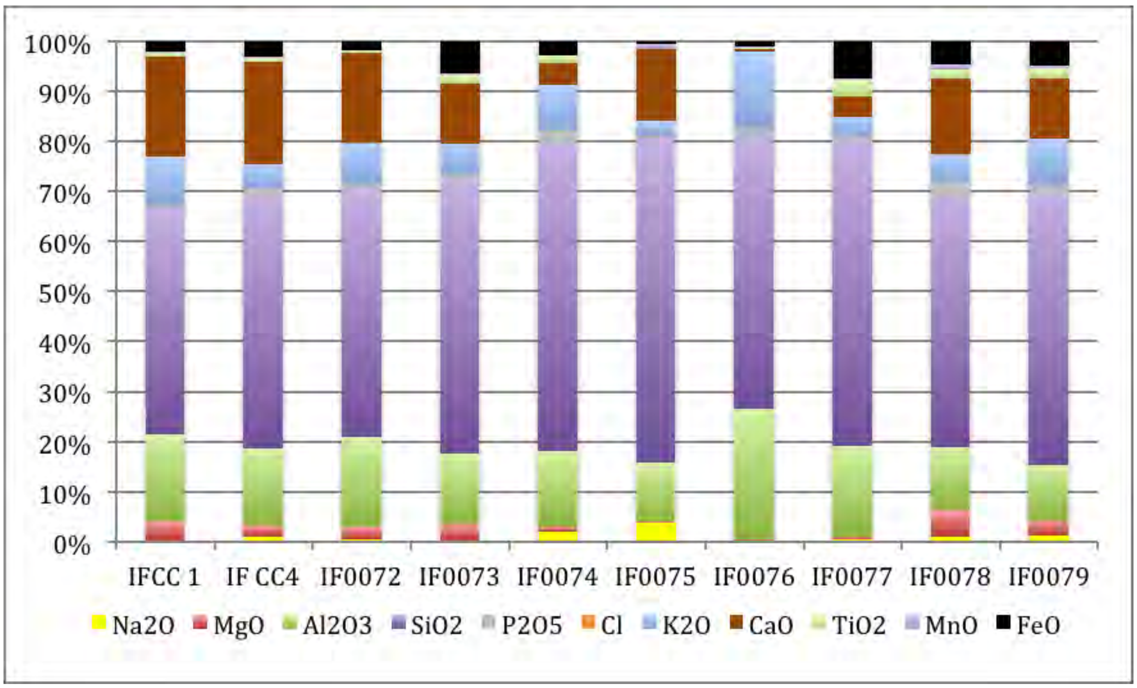


Figure 8.19. Cumulative percentage frequency of the composition of the outer glassy coating (see data in Table 8.6).

Crucible Fabric. Results of the compositional analysis of the fabric reveal compositional similarities among all the samples, which are characterized by very high alumina content (25– 40%) and significantly low lime (<5%) (Figs. 8.20–22 and 8.23). The notably high alumina is likely connected to the source and type of clay, as Lankton *et al* (2006: 135) have previously suggested. Comparison of the crucible composition with local ceramics and the geological elements of the site and its surrounding area will help to determine whether local clay was used for the crucibles.

Although overall the crucible fabric appears to be similar, some subtle compositional variations exist. The concentration of soda is generally low. Figure 8.24 shows that Na_2O ranges between 0% and 3%. However, occasionally there are some elevated soda values, especially in the fabric close to the transition. The elevated soda, up to 4% in few cases, is sometimes connected to lime concentrations above 1%. Two instances of high Na_2O-Al_2O_3-CaO occur in an area that seemed more vitrified than the surrounding fabric; this may be glass that leaked through a crack present in the fabric matrix or "a plagioclase feldspar" (Rehren 2014, personal communication). The low soda in the crucible fabric, although not unexpected, shows that the clay was not from a sodium-rich source. However, the elevated soda in the area close to the transition, with concomitant low MgO, may indicate contamination resulting from the fluidity of elements between the fabric and the glass.

There is consistently low magnesium in the crucible fabric (Fig. 8.24). The concentration of potash varies widely. However, on average, the outer body has higher potash than the inner body. Similarly, the concentration of iron varies among the samples. Although it occurs in low concentration, the percentage of iron oxide is not connected to other oxides. Thus, at the moment we cannot say much about iron oxide other than it varies among the samples.

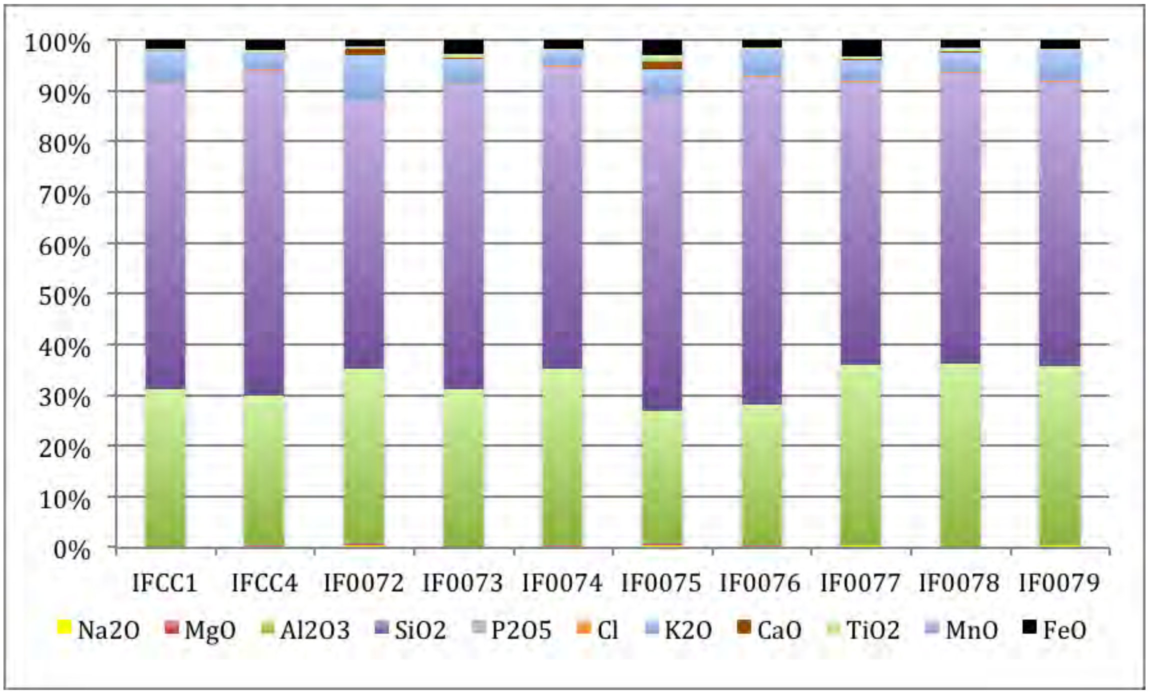


Figure 8.20. Cumulative percentage frequency of the composition of the outer crucible fabric (see data in Table 8.6).

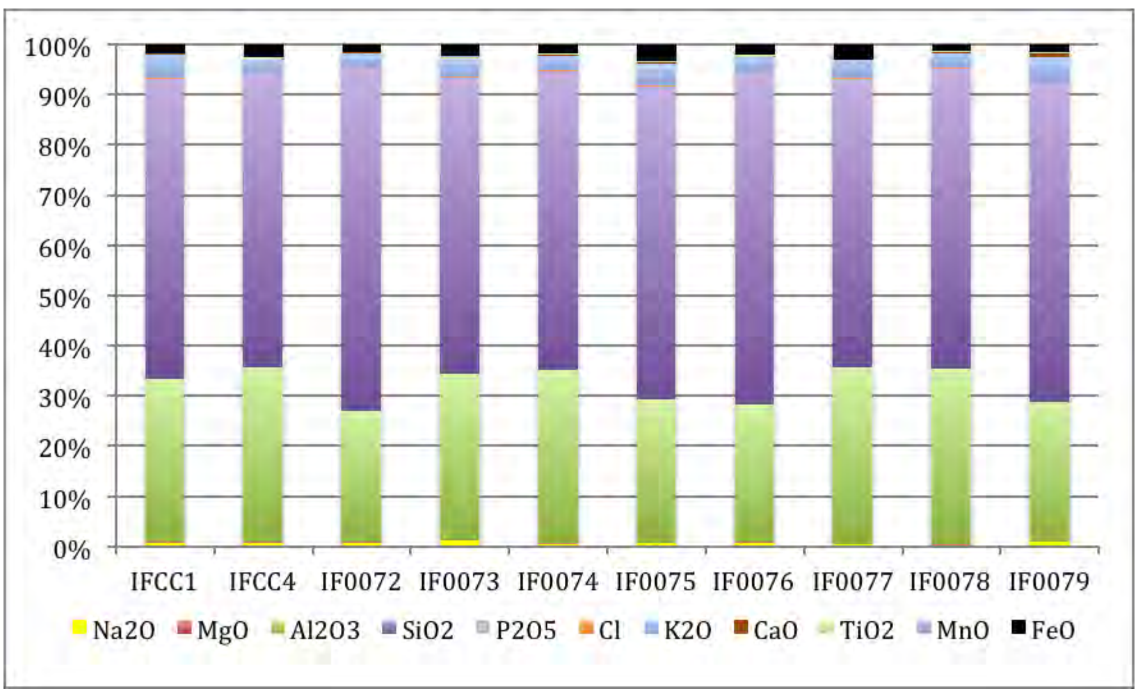


Figure 8.21. Cumulative percentage frequency of the composition of the inner crucible fabric (see data in Table 8.6).

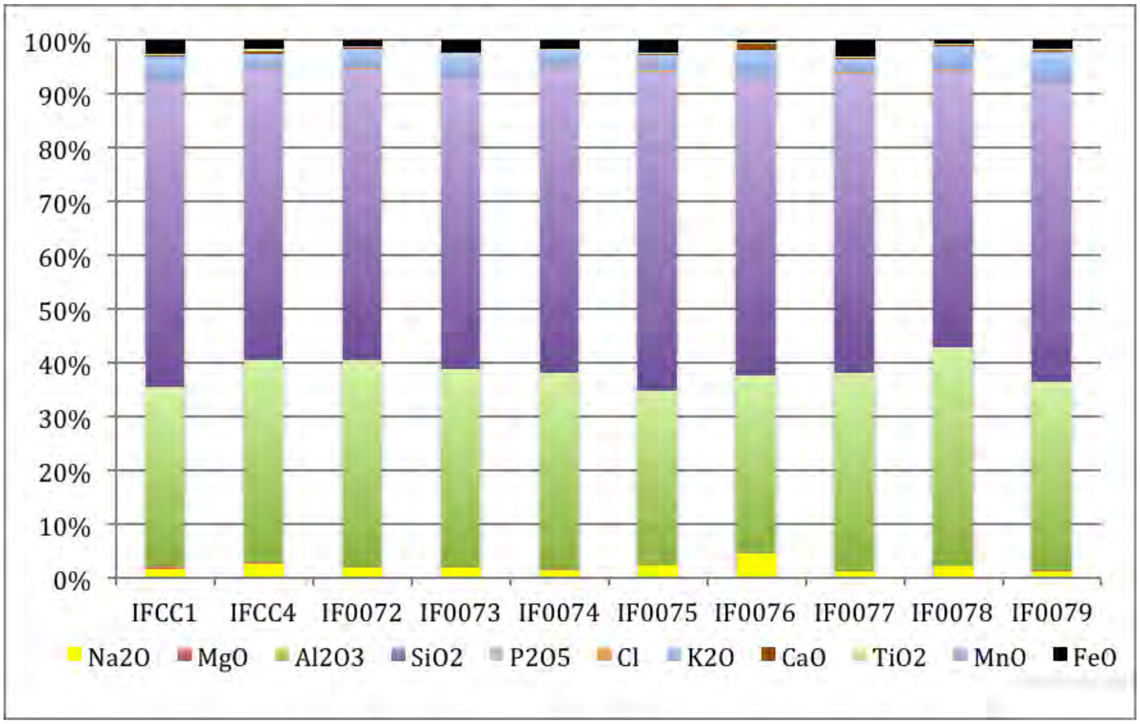


Figure 8.22. Cumulative percentage frequency of the composition of the crucible fabric in the transition zone (see data in Table 8.6).

Outer coating	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	Cl	K_2O	CaO	TiO_2	MnO	FeO	Total
IFCC 1	0.2	3.8	17.5	45.3	0.6	0.0	9.6	20.0	0.7	0.3	2.0	100.0
IF CC4	1.0	2.3	15.4	50.5	1.3	0.0	5.0	20.3	0.8	0.2	3.1	100.0
IF0072	0.6	3.1	16.5	47.9	1.0	0.0	7.3	20.2	0.7	0.3	2.6	100.0
IF0073	0.2	3.2	14.1	54.8	1.0	0.0	6.2	12.1	1.7	0.3	6.4	100.0
IF0074	2.1	1.0	15.2	61.2	2.8	0.0	8.9	4.5	1.4	0.2	2.7	100.0
IF0075	3.9	0.2	11.9	64.9	0.2	0.0	3.2	14.2	0.2	0.9	0.5	100.0
IF0076	0.2	0.2	26.0	55.2	0.8	0.0	15.4	0.7	0.3	0.1	1.1	100.0
IF0077	0.5	0.6	18.0	61.2	0.7	0.0	3.8	4.3	3.3	0.1	7.5	100.0
IF0078	0.5	2.7	18.1	52.2	1.5	0.1	13.3	7.7	1.1	0.5	2.4	100.0
IF0079	1.2	3.1	11.0	54.6	1.5	0.0	9.1	12.1	2.0	0.5	4.9	100.0
Outer body												
IFCC 1	0.1	0.1	30.9	60.7	0.1	0.0	6.0	0.1	0.3	0.1	1.7	100.0
IF CC4	0.2	0.2	29.5	64.1	0.2	0.0	3.3	0.1	0.5	0.0	2.0	100.0
IF0072	0.3	0.7	34.2	53.0	0.1	0.0	8.7	1.4	0.2	0.1	1.4	100.0
IF0073	0.1	0.1	31.0	60.1	0.1	0.0	5.0	0.2	0.7	0.1	2.7	100.0
IF0074	1.7	0.7	26.8	53.9	0.9	0.0	10.7	3.1	0.5	0.0	1.7	100.0
IF0075	0.4	0.6	25.8	61.8	0.3	0.1	5.1	1.7	1.1	0.1	3.0	100.0
IF0076	0.2	0.2	27.8	64.5	0.0	0.1	5.3	0.2	0.2	0.0	1.4	100.0
IF0077	0.3	0.2	35.6	55.5	0.2	0.2	4.1	0.4	0.3	0.0	3.3	100.0
IF0078	0.1	0.1	36.0	57.2	0.0	0.3	4.0	0.1	0.7	0.0	1.6	100.0
IF0079	0.4	0.4	34.3	55.6	0.2	0.1	6.5	0.5	0.3	0.0	1.7	100.0

Table 8.6: Chemical composition of oxides by percentage of weight of all the areas analyzed in the crucibles.

In body-fabric	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	MnO	FeO	Total
IFCC 1	0.8	0.1	32.5	59.9	0.0	4.7	0.1	0.1	0.0	1.8	100.0
IFCC4	0.7	0.2	34.9	58.5	0.0	2.4	0.1	0.6	0.0	2.5	100.0
IF0072	0.7	0.2	26.1	68.3	0.0	2.7	0.2	0.1	0.0	1.5	100.0
IF0073	1.3	0.1	33.0	59.0	0.0	3.6	0.1	0.3	0.1	2.4	100.0
IF0074	0.5	0.2	34.5	59.5	0.0	3.0	0.2	0.2	0.0	1.8	100.0
IF0075	0.6	0.1	28.7	62.2	0.1	4.5	0.1	0.3	0.0	3.2	100.0
IF0076	0.8	0.1	27.5	66.2	0.0	2.7	0.1	0.5	0.0	2.0	100.0
IF0077	0.4	0.2	35.1	57.2	0.2	3.5	0.1	0.1	0.0	3.0	100.0
IF0078	0.3	0.1	35.1	59.6	0.0	3.0	0.1	0.2	0.0	1.4	100.0
IF0079	0.9	0.1	27.8	63.8	0.0	4.8	0.7	0.2	0.1	1.6	100.0
In body trans											
IFCC 1	1.6	0.4	33.3	56.9	0.0	4.6	0.2	0.2	0.1	2.6	100.0
IF CC4	2.6	0.2	37.6	54.1	0.1	2.7	0.3	0.5	0.0	1.7	99.9
IF0072	1.8	0.2	38.6	54.0	0.1	3.6	0.2	0.1	0.1	1.3	100.0
IF0073	1.8	0.0	36.9	54.3	0.0	4.0	0.2	0.2	0.2	2.4	100.0
IF0074	1.4	0.2	36.6	57.0	0.1	2.7	0.2	0.2	0.0	1.6	100.0
IF0075	2.3	0.1	32.2	59.5	0.0	2.8	0.2	0.3	0.0	2.4	100.0
IF0076	4.5	0.0	33.0	55.9	0.0	4.7	1.2	0.1	0.1	0.5	100.0
IF0077	1.1	0.1	36.9	55.4	0.3	2.6	0.1	0.2	0.0	3.2	100.0
IF0078	2.0	0.1	40.8	51.3	0.0	4.4	0.3	0.0	0.1	0.8	100.0
IF0079	1.3	0.1	35.2	55.5	0.1	5.5	0.4	0.3	0.0	1.6	100.0

Table 8.6 (cont.), Chemical composition of oxides by percentage of weight of all the areas analyzed in the crucibles.

In glass trans	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	MnO	FeO	Total
IFCC1	2.6	0.3	27.1	58.3	0.0	5.8	3.6	0.1	0.2	2.0	100.0
IFCC4	5.8	0.1	19.9	60.3	0.2	3.2	9.0	0.2	0.2	1.2	100.0
IF0072	4.3	0.2	19.2	67.2	0.2	6.9	0.5	0.0	0.1	1.4	100.0
IF0073	4.6	0.1	23.0	58.0	0.2	6.5	4.7	0.5	0.2	2.2	100.0
IF0074	4.3	0.1	16.7	62.8	0.2	4.1	10.8	0.0	0.4	0.6	100.0
IF0075	4.8	0.0	14.3	65.9	0.2	2.8	10.0	0.2	0.7	1.1	100.0
IF0076	4.2	0.0	13.1	66.0	0.2	3.6	11.3	0.1	0.9	0.6	100.0
IF0077	8.4	0.6	17.1	61.8	0.5	6.9	1.3	0.1	0.7	1.9	100.0
IF0078	5.1	0.1	34.7	51.4	0.0	5.5	2.6	0.0	0.0	0.6	100.0
In glass											
IFCC1	2.9	0.1	13.1	61.1	0.1	4.3	16.7	0.1	1.0	0.8	100.0
IFCC4	6.1	0.0	12.4	64.0	0.1	1.0	15.0	0.0	0.1	1.1	100.0
IF0072	4.7	1.4	12.5	66.6	0.4	5.7	3.1	0.2	0.1	5.1	100.0
IF0073	3.6	0.1	14.5	64.0	0.0	5.3	10.1	0.1	0.6	1.7	100.0
IF0074	3.9	0.1	13.7	63.4	0.1	3.8	13.8	0.0	0.7	0.5	100.0
IF0075	4.7	0.0	24.0	58.9	0.1	2.2	8.8	0.3	0.3	0.7	100.0
IF0076	4.2	0.1	13.6	65.1	0.1	3.7	11.8	0.1	0.9	0.6	100.0
IF0077	8.1	1.1	12.3	65.2	0.4	6.4	2.4	0.1	1.3	1.5	100.0
IF0078	4.4	0.0	16.2	65.3	0.3	5.2	7.7	0.0	0.1	0.7	100.0
IF0079	1.8	0.1	13.4	63.7	0.1	5.2	13.4	0.2	1.1	1.1	100.0

Table 8.6 (cont.). Chemical composition of oxides by percentage of weight of all the areas analyzed in the crucibles.

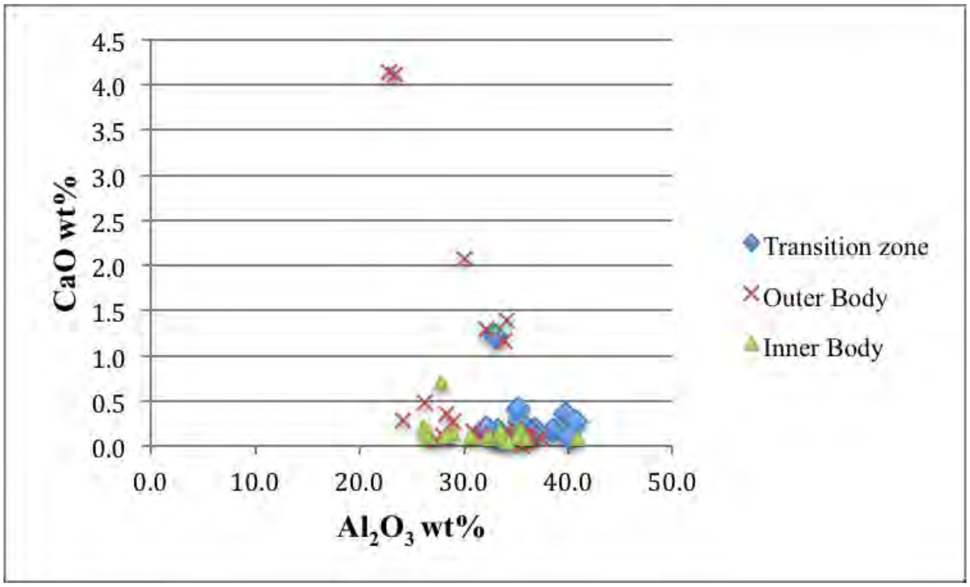


Figure 8.23: Percentage concentration of Al_2O_3 and CaO in each segment of the crucible fabric.

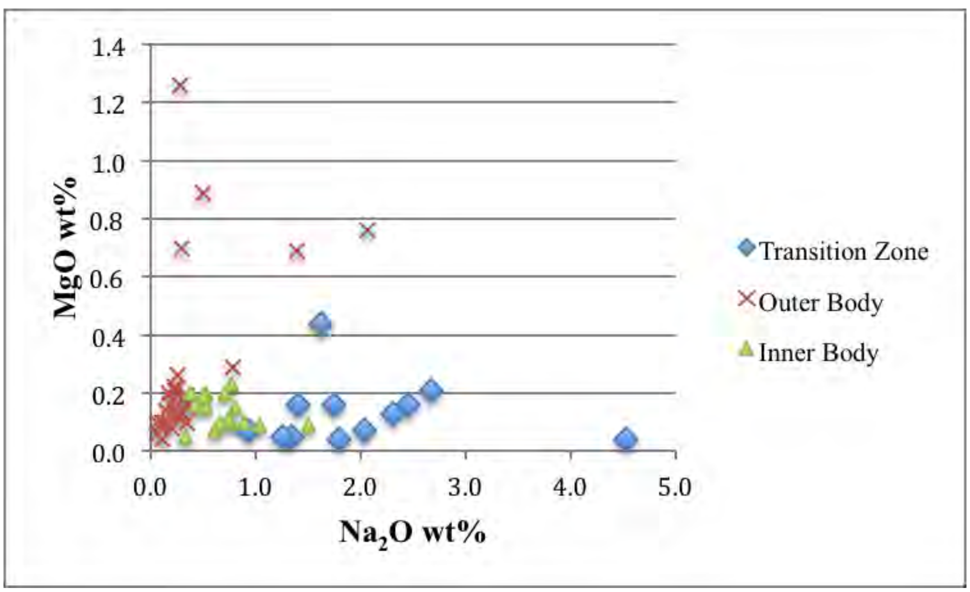


Figure 8.24: Percentage concentration of Na_2O and MgO in each segment of the crucible fabric.

Inner glass. Chemical analysis reveals high levels of alumina (generally 12-15%), Fig. 8.25) in all the samples analyzed, including samples analyzed by Dr. Laure Dussubieux using LA-ICP-MS (see Appendix D.2). This is consistent with the known compositional groups for Ile-Ife glass, which include both a high lime high alumina (HLHA) group (Lankton *et al* 2006; Ige 2010a&b) and low lime high alumina group (LLHA). There are two cases of unusually high alumina (up to 33%) in the crucibles under study, which could be due to contamination from the crucible fabric (Table 8.6). In the HLHA group, the lime concentration ranges between 11% and 16%. While the HLHA glass is low in magnesium oxide, LLHA has elevated magnesia up to about 2%. The concentration of soda and potash varies significantly, with the highest soda concentration in LLHA glass. Chlorine is significantly absent in the glass. Chlorine is an important element associated with mineral natron and plant ash glass (Freestone 2006:140; Tanimoto and Rehren 2008). Its absence or presence in the inner glass will help to further understand the source of alkalis for Ile-Ife glass.

Colorant oxides present include manganese, iron, and copper. There is no significant connection between manganese and iron concentration in relation to the glass color. Although the concentration varies widely, their values are, in part, enough to give some color tint to the glass batch. However, copper concentration is related to high iron, which is equally restricted to LLHA glass (Table 8.6).

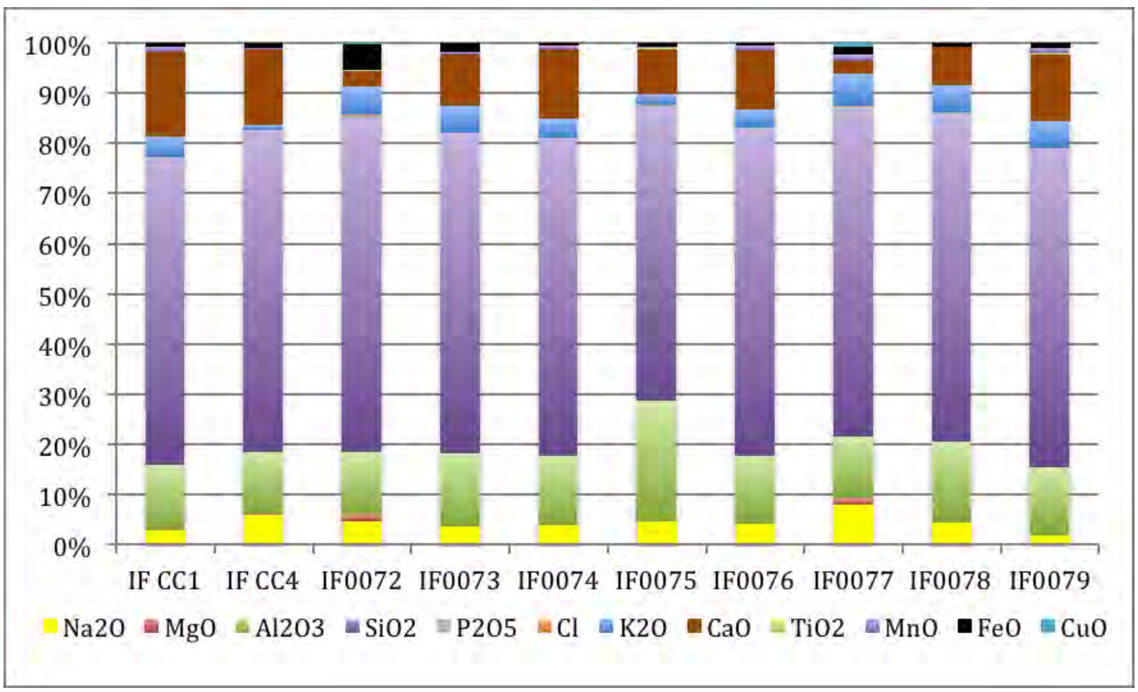


Figure 8.25. Cumulative percentage frequency of the composition of the crucible inner glass (see data in Table 8.6).

Glass in the inner transition zone. In terms of the basic diagnostic elements for glass, glass in the interior close to the transition zone is compositionally similar to the 'main' interior glass with high lime, high alumina characteristics (Fig. 8.26). This pattern seems consistent among the samples except for IF0072 and IF0077 where lime is unusually low. Overall, about half the samples have alumina concentration above 20%. Such elevated levels are not unexpected, as the alumina could have leached into the glass in the transition zone from the fabric.

The concentration of the two major alkalis, soda and potash, is consistent with the general pattern for Ile-Ife glass. This consistency suggests that there is no significant difference between the interior glass and the glass in the transition zone in terms of the concentration of alkalis. In addition, MgO and P_2O_5 are low in the composition. The low value of MgO and P_2O_5 also falls within the range for Ile-Ife glass, especially as observed in the interior glass.

Iron oxide content varies widely in the samples. Other possible colorant oxides present are MnO and Cu. Although manganese occurs in most samples, its concentration is low across the samples. Copper oxide is not common in the samples, occurring only in samples IF0072 and IF0077 in very low concentration, although enough for colorants (Table 8.6).

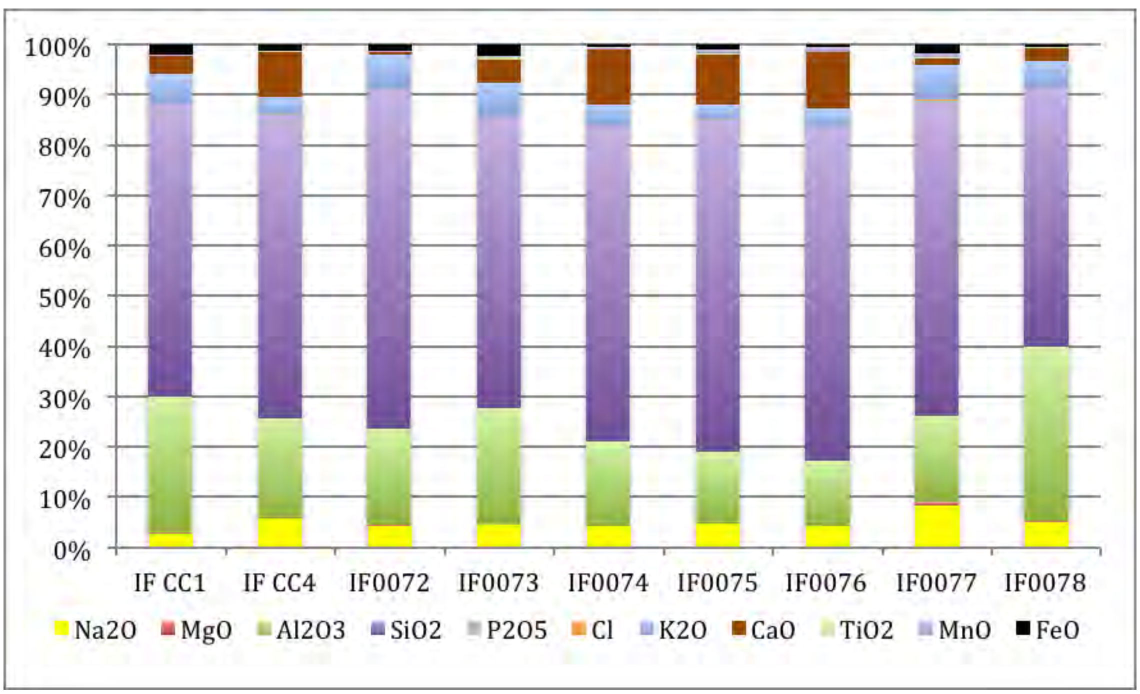


Figure 8.26. Cumulative percentage frequency of the composition of the glass in the transition zone of the crucible (see data in Table 8.6).

Droplets and Glass Beads

Three partially corroded glass beads (IF0083 and IF0084) and three droplets (IF0085) and were analyzed (Table 8.7; Appendix E.5). SEM analysis showed all samples to be homogeneously vitrified with no significant visible microstructure. Corroded beads that are white in appearance revealed a blue tint when prepared for analysis, suggesting that some of the white beads recovered may originally have been blue or some other color before the surface corroded. However, observation of one of the glass beads under different light magnifications revealed some opaque milky appearance, which may suggest it was originally white glass. Further work with the assemblage will need to be completed before any conclusions can be made about the white glass. However, it is not impossible that Ile-Ife produced white glass, as some of the glass beads are decorated with white stripes (see Chapter 7).

Unit	Level	Sample #	Type	Color	Diameter	Comments
IO-C	5	IF0083a	Tubular Bead	White	0.5	Partial patination. Examination under an optical microscope shown that it may be colored.
IO-C	5	IF0083b	Oblate Bead	White	0.3	Heavily corroded. Examination under an optical microscope shown that it may be colored.
IO-B	7	IF0084	Cylindrical Bead	White	0.4	Cylinder bead partially corroded in devitrification process.
IO-C	5	IF0085	Droplets	Blue, Green, and White		The green and white are corroded with patination around they. Their true color was revealed after embedded in resin and grounded. Although the blue color is identifiable before preparation, it becomes more apparent after it was prepared.

Table 8.7: Provenience and description of the glass material analyzed by SEM-EDS

EDS Analysis of Chemical Composition

Results of the analysis show an interesting difference in chemical composition between the glass beads and the droplets (Fig. 8.27; Appendix E.8). The three glass beads analyzed reveal the typical Ile-Ife HLHA glass composition. All recognized elements in the glass bead samples are consistent with HLHA composition. However, the concentration of potash is significantly high in IF0083 (tubular) and IF0084 with an average of 8.5% (Fig. 8.27), which is higher than the average suggested for both HLHA and LLHA Ile-Ife glass (Dussubieux 2013 Appendix D. 2).

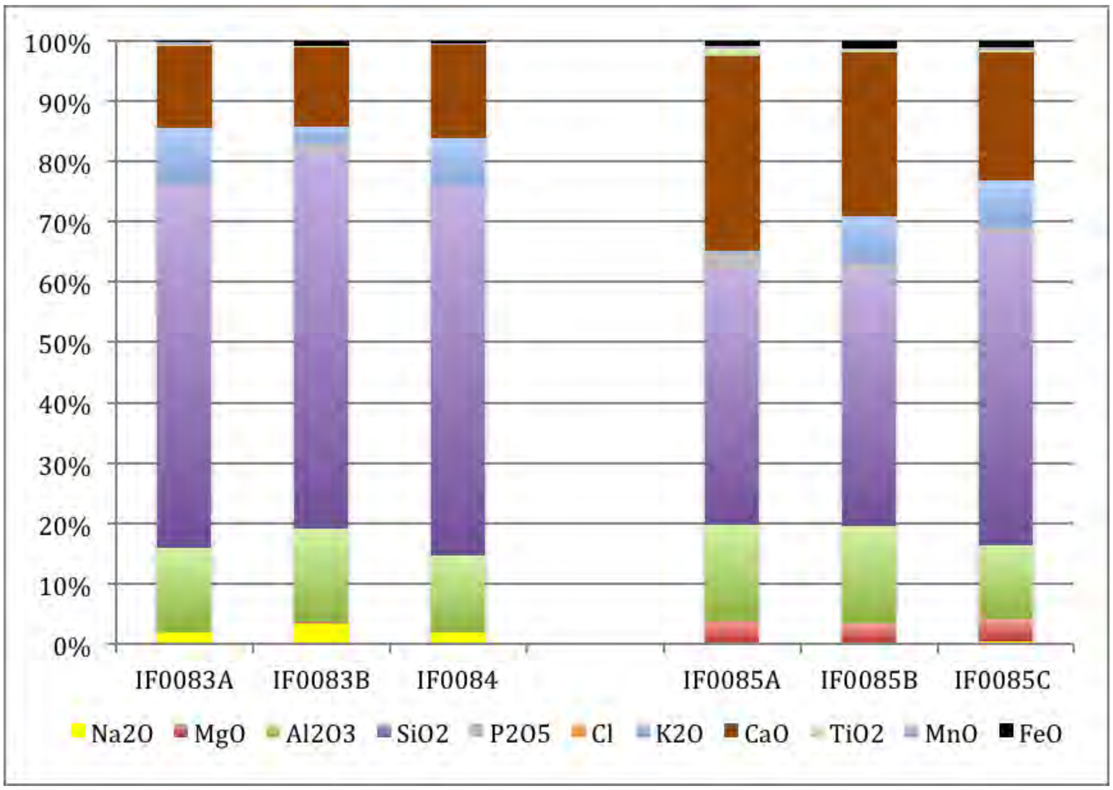


Figure 8.27: Comparative cumulative percentage frequency of the composition of the corroded glass beads (IF0083 A & B, IF0083) and glass droplets (IF0085 A, B, & C).

Although the droplets also have high concentrations of potash, overall there is a stark contrast between the two groups. The droplets have low concentration of both silica and alkali (soda), but high concentration of other elements such as magnesium, alumina, lime, and phosphorus when compared with the composition of glass beads (Fig. 8.28). As shown in Figure 8.29 although the concentration of alumina in the droplets is in the general range expected for HLHA glass, the lime concentration is unusually high (21%-32%). This extremely high content of lime in the droplets is not seen in other material analyzed so far from Ile-Ife and thus could have implications for our understanding of the formation process and the constituents of the droplets.

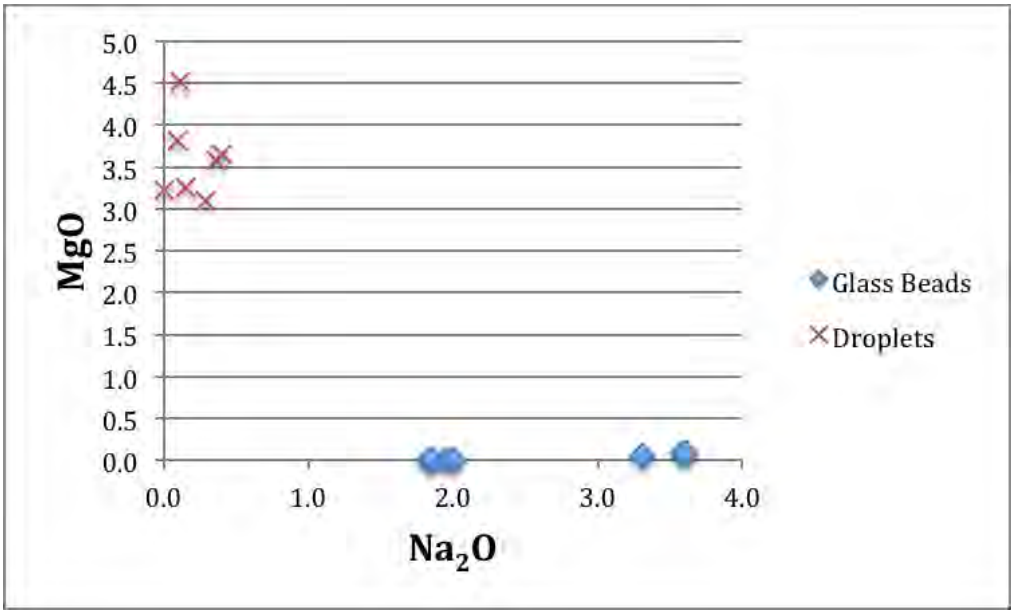


Figure 8.28: Percentage concentration of MgO and Na_2O in the corroded glass beads and glass droplets.

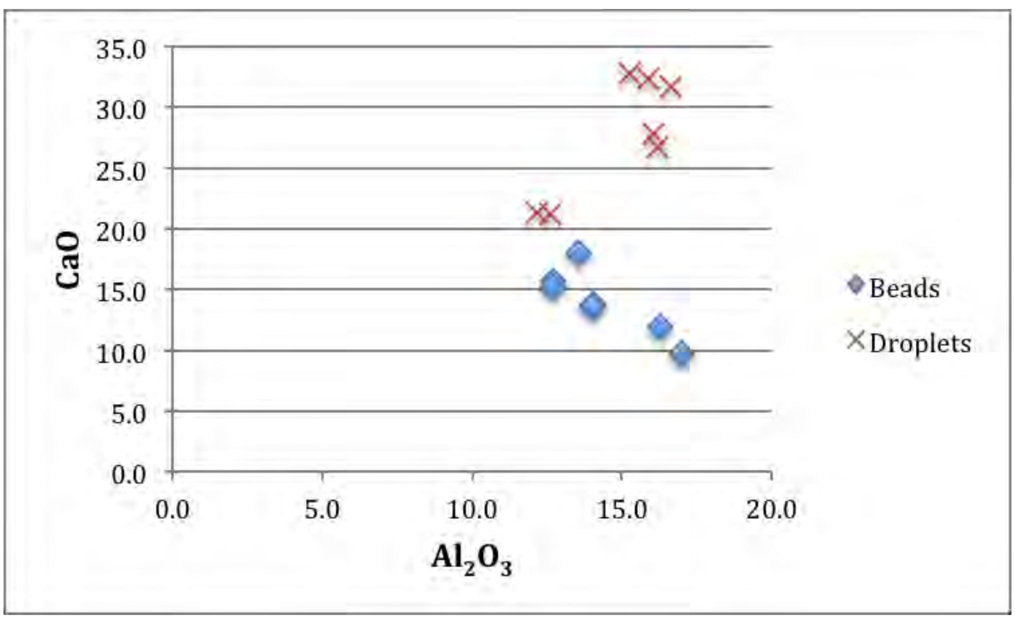


Figure 8.29: Percentage concentration of Al_2O_3 and CaO in the corroded glass beads and glass droplets.

Manganese and iron are the only colorant oxides detected by SEM-EDS in the composition of the droplets. However, their concentration is similar to what was observed in other glass materials (e.g. beads, waste, crucible interior glass). Therefore, it is difficult to link the concentration of the colorants oxides to the droplets' colors. The only suggestion that can be made now is that the colors may have been derived from contamination in the production process; this is an area that needs closer examination.

Vitrified Production Debris (VPD)

The true nature and function of the VPD in relation to glass production is still largely unknown. We considered whether they were remains of the raw material of glass making (i.e. the silica source) or alternatively they may have been part of the furnace installation that served to fire the crucibles. It was hoped that examination of the microstructure and composition would help to investigate the material and its possible function. Five samples (3 from Unit IO-C and 2 from Unit IO-BD) were selected for SEM-EDS analysis (Appendix E.5). More analysis of these objects is planned for the future.

Visual observation and microscopic study of sample cross sections affirmed that there are two different areas to be considered: a light grayish/whitish area either within the matrix of the samples or on the outside; and a black, partially vitrified area. These areas were identified, in part, by their degree of vitrification, which corresponded with the visual color of the two areas. Often, the two blend together such that one could not see any dividing line or crack along the meeting point. Although the two areas are of a different degree of vitrification, the boundary is fuzzy.

One thing is noticeable about sample IF0095: this sample has a chunk of quartz firmly attached to its black area (Appendix E.5). The coarseness and pureness of the quartz may suggest that it was fixed to the vitrified material when still hot. However, a line of black vitrified material in between the quartz may suggest something more complex than the above explanation.

SEM Analysis of Microstructure

Examination of the samples at different magnifications on the SEM revealed the presence of quartz grains in both the black and whitish areas (Fig. 8.30, Fig. 8.31). There are more quartz grains in the black area then the white area. The quartz grains are in various shapes and sizes, and they appear to be partially fused to the matrix with visible thermal cracks. There is a mass of raw quartz grains in the black area of IF0095 (Appendix E.5) compared to other samples. These raw quartz grains were present while the black area was in the process of vitrification. Observation of the black area under high SEM magnification shows an interesting microstructure that is absent in the white area. This microstructure consists of different crystals, some of which are white needle or sheet-like, which appears diagonally. Other crystals are chunky, angular, and dark gray in a light grayish matrix. Each of these crystals, as well as the matrix of the two areas, was analyzed for composition and the results are discussed below.

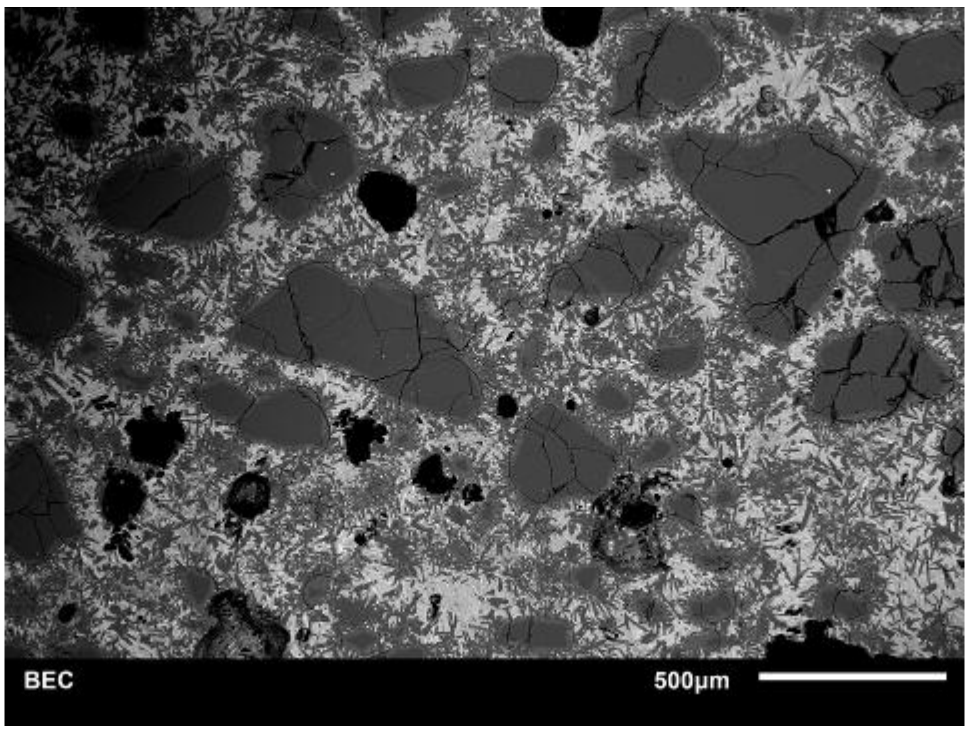


Figure 8.30. Backscatter SEM image of the black area of the VPD

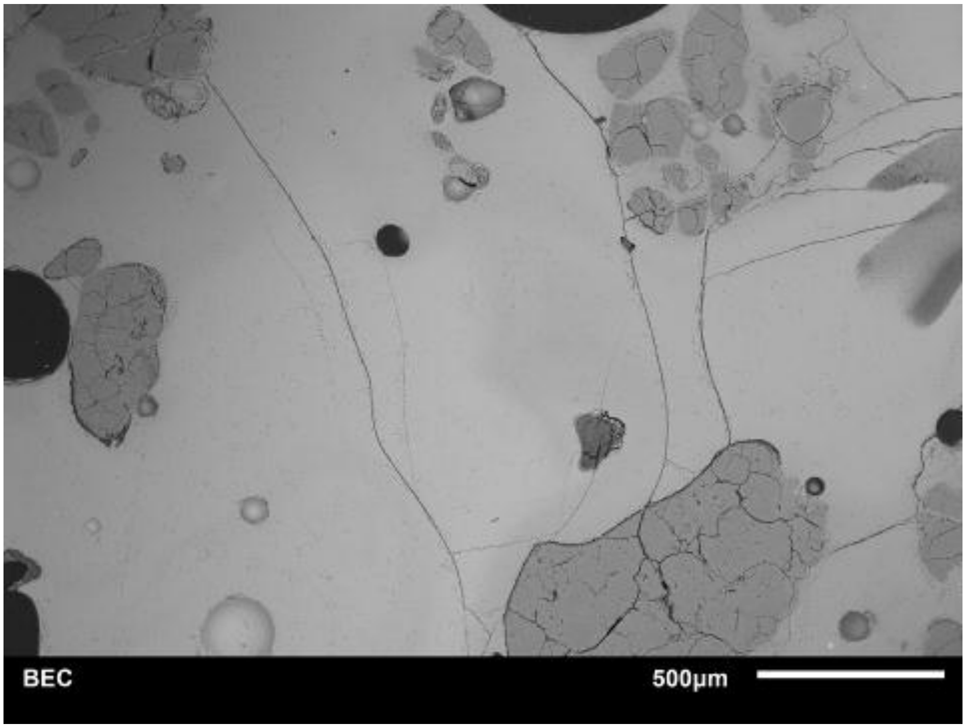


Figure 8.31. Backscatter SEM image of the white area of the VPD

EDS Analysis of Chemical Composition

The focus of interest in these analyses is detection of differences in composition between the black and white-colored areas of the VPD (Figs. 8.32 and 8.33; Table 8.8). The concentration of silica is consistent in the two areas ranging between 65% and 75%. Compared to the white area, the concentration of iron oxide is high in the black area averaging 10%. This high iron oxide content is likely to account for the blackness; clay with high FeO turns to black under high temperature. Also, FeO oxide has been used among ancient societies as recipe for making black glass (Rehren *et al* 2012; Cholakova and Rehren 2014). The high FeO (11.2 wt%) in the black area is connected with high TiO_2 (4.8 wt%), while the white area is mostly characterized with low FeO (5.9 wt%) and TiO_2 (2.9 wt%) (Fig. 8.34).

There is a significantly low concentration of soda (<0.3%) in the two areas. However, potash, magnesia, and lime are high in the white area, but overall low in the black area (Fig. 8.35). In terms of the concentration of alumina, the black area seems to have high alumina (8%–15%). The concentration of phosphorus is relatively high in the white area (0.7%–1.2%) compared to ≤0.5% in the black area. This level of elevated phosphorus is not seen in the inner glass and fabric of the samples analyzed.

As stated above, two forms of crystals characterize the black area: needle-like and chunky forms, which reveal variation in chemical composition between the two areas (Appendix E.9). The needle-like white crystals are very rich in titanium and iron oxides with values up to 55.3% and 44.2%, respectively. The shape and composition indicate that the crystals are likely to be newly formed ilmenite $FeTiO_3$ (Rehren 2014, personal communication). On the other hand, the chunky dark gray crystals are very high in alumina, averaging approximately 60%. The content of siO_2 is low (<30%), with TiO_2 and Fe concentration <2% in the crystal In one case, the high alumina in the dark gray chunky crystal is connected to high iron oxide (38%). All other oxides are either below detectable level or completely absent. Questions to be asked about these differences between the white and black area of the VPD include: what factor would have caused the variations in composition between the two areas? what does the concentration of the elements have to offer with regard to the nature of the material?

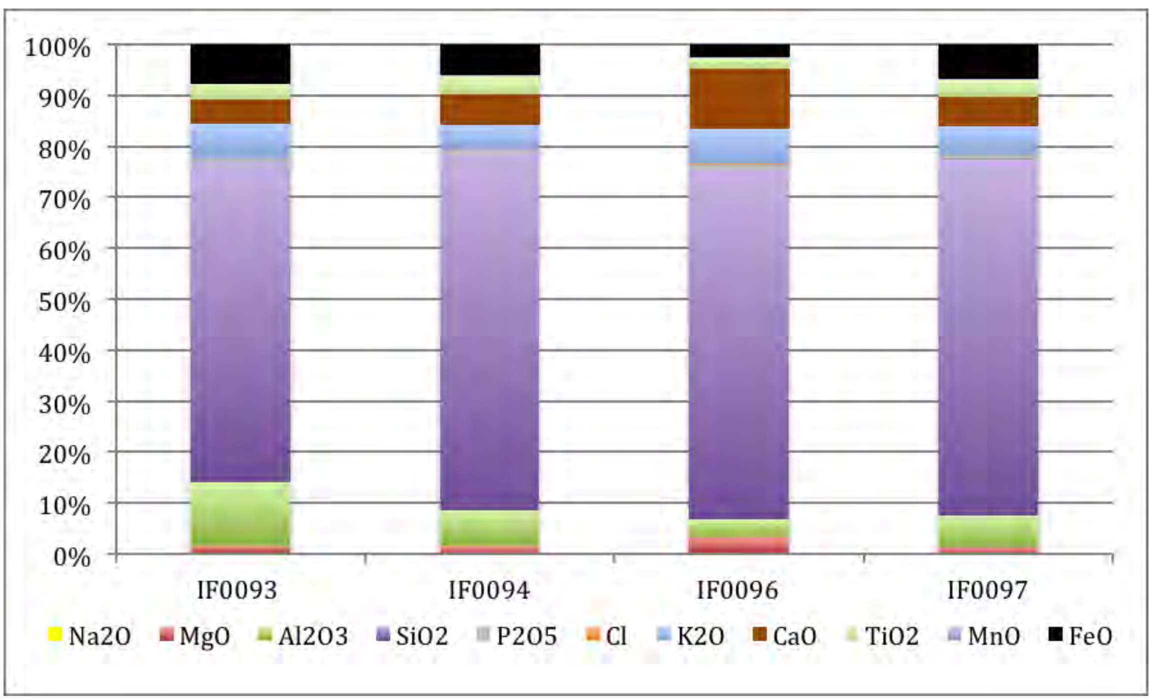


Figure 8.32. Cumulative frequency distribution of detected elements in the white area of the VPD

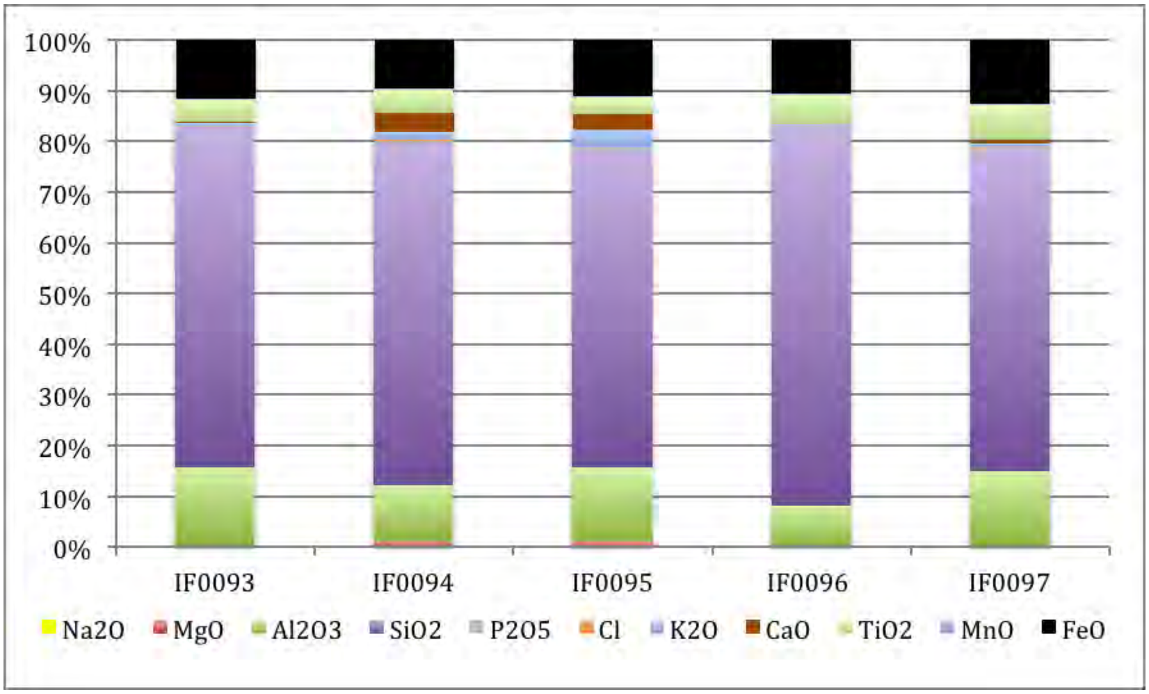


Figure 8.33. Cumulative frequency distribution of detected elements in the black area of the VPD.

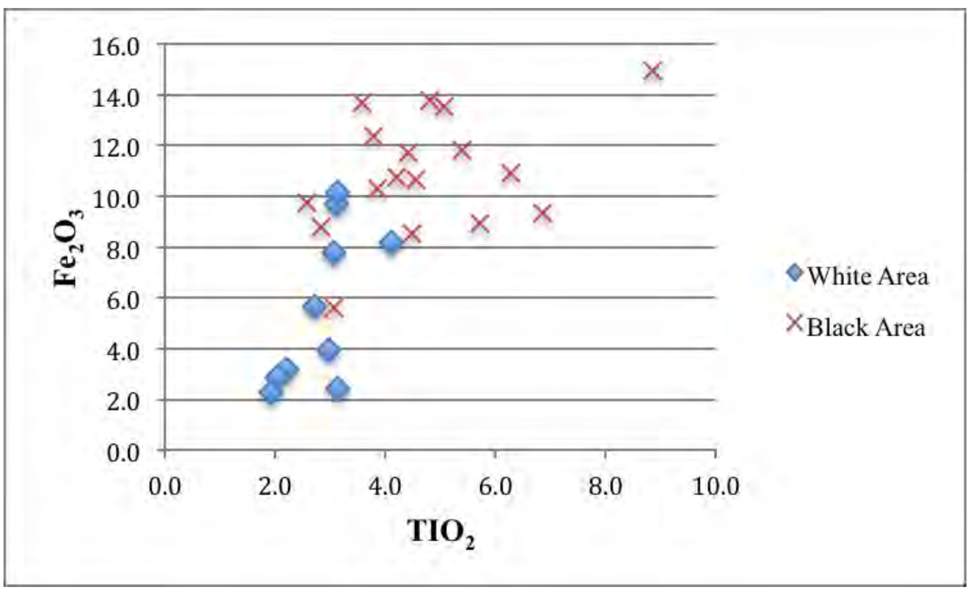


Figure 8.34. Concentration of Fe_2O_3 and TiO_2 in the white and black areas of the VPD from Ile-Ife.

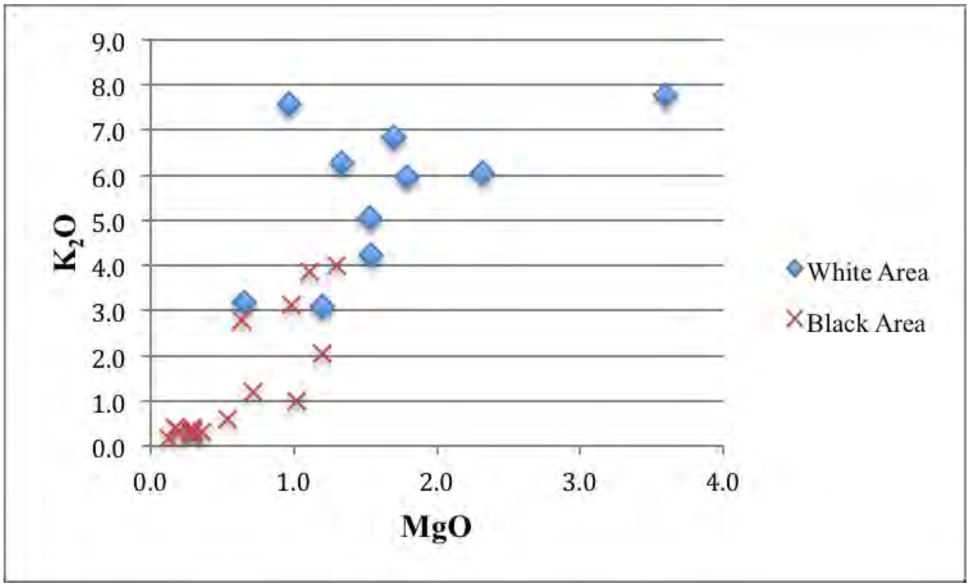


Figure 8.35. Concentration of K_2O and MgO in the white and black areas of the VPD from Ile-Ife.

Sample / White area	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	MnO	FeO	Total
IF0093	0.2	1.8	12.3	59.4	1.1	6.0	6.2	3.1	0.2	9.7	100.0
	0.3	1.0	12.9	66.0	0.5	7.6	3.2	2.7	0.1	5.7	100.0
IF0094	0.0	1.5	6.5	73.6	0.8	4.3	6.2	3.0	0.1	4.0	100.0
	0.1	1.5	7.7	66.4	0.7	5.1	5.9	4.1	0.3	8.2	100.0
IF0096	0.3	3.6	3.4	63.8	1.4	7.8	15.1	1.9	0.3	2.3	100.0
	0.2	2.3	3.5	73.5	1.0	6.1	8.3	2.0	0.2	2.9	100.0
IF0097	0.1	1.3	7.9	64.4	1.2	6.3	5.2	3.1	0.3	10.2	100.0
	0.2	1.7	7.2	64.2	1.3	6.9	7.2	3.1	0.4	7.8	100.0
	0.1	0.7	3.4	81.4	0.6	3.2	5.2	3.1	0.1	2.5	100.0
Average	**0.2**	**1.7**	**7.2**	**68.1**	**1.0**	**5.9**	**6.9**	**2.9**	**0.2**	**5.9**	**100.0**
Sample / Black area											
IF0093	0.1	0.4	16.7	62.9	0.4	0.3	0.4	4.8	0.2	13.8	100.0
	0.1	0.3	15.3	66.9	0.4	0.3	0.4	4.4	0.2	11.7	100.0
	0.1	0.2	14.2	70.4	0.3	0.3	0.3	3.9	0.1	10.3	100.0
	0.1	0.3	15.7	67.7	0.4	0.4	0.4	4.2	0.1	10.8	100.0
IF0094	0.2	1.0	11.6	66.9	0.6	1.0	3.3	4.6	0.3	10.7	100.0
	0.1	1.2	10.4	68.1	0.5	2.1	4.6	4.5	0.0	8.5	100.0
IF0095	0.1	1.1	12.9	66.2	0.4	3.9	3.4	2.8	0.3	8.8	100.0
	0.2	0.6	11.7	69.5	0.4	2.8	2.3	2.6	0.2	9.8	100.0
	0.2	1.3	17.3	56.2	0.5	4.0	3.9	3.8	0.3	12.4	99.9
	0.2	1.0	16.2	58.4	0.5	3.1	3.0	3.6	0.3	13.7	100.0
IF0096	0.1	0.1	7.5	74.3	0.2	0.2	0.2	5.4	0.1	11.8	99.9
	0.0	0.3	7.5	76.8	0.2	0.3	0.1	5.7	0.2	8.9	100.0
	0.1	0.3	8.8	72.7	0.1	0.3	0.2	6.3	0.2	10.9	100.0
IF0097	0.2	0.2	12.5	67.0	0.3	0.4	0.5	5.1	0.2	13.6	100.0
	0.3	0.5	16.9	56.2	0.6	0.6	0.7	8.9	0.4	14.9	100.0
	0.0	0.3	14.3	67.5	0.4	0.4	0.8	6.9	0.1	9.4	100.0
Average	**0.1**	**0.6**	**13.1**	**66.7**	**0.4**	**1.3**	**1.5**	**4.8**	**0.2**	**11.2**	**100.0**

Table 8.8: Chemical composition of the white and black areas of the vitrified production debris by SEM-EDS.

Ceramic Cylinders

Three ceramic cylinder fragments were tested by SEM-EDS (Appendix E.5, Table 8.9) to determine their bulk composition and the nature of some glassy-whitish material on their surfaces. Appendix E.10 show the results of all the areas analyzed, permitting comparison with the domestic pottery and crucibles.

SEM Analysis for Microstructure

Examination of the ceramic cylinders for microstructure shows three areas: an external whitish gray area which is the outer coating, a caramic area immediately fronting the whitish-gray outer coating, and an area at the core of the sample. The fabric of the samples vary from gray to red/orange color. This color variation may have resulted from intensity of firing (Fig. 8.36). The outer glassy coating appears heterogeneous with some whitish needle-like crystals and patches of dark gray present. Voids and/or vesicles are also visible in the matrix.

In terms of structure and inclusions, the samples are similar to each other. Circular and elongated voids and quartz grains are present in the core. Presently, it is uncertain wheather the elongated voids represent organic temper. Mica is present in the clay fabric, which is a natural component of local clays (Ige and Ogunfolakan 2009; Ige 2010b). However, the distinguishing factor between the inner layer immediately fronting the outer coating and the center core is the degree of firing or vitrification. As a result, the inner core appears to be less vitrified than the inner layer immediately fronting the coating.

Unit	Level	Sample #	Ceramic type	Diameter (cm)	Paste Color	Non-Plastic Inclusions	Comments
IO-C	4	IF0080	Ceramic cylinder	2.6	Red	Grog, quartz	Whitish encrustation on the surface covers more than half of the circumference. Core is black
IO-D	7	IF0081	Ceramic cylinder	2.1	Gray	Grog, quartz	No surface encrustation. Surrounding core is orange; center core is gray
IO-B	8	IF0082	Ceramic cylinder	1.9	Black	Grog, quartz	Whitish encrustation on the surface, limited to opposite areas along the ceramic diameter
IO-B	4	IF0086	Domestic pottery		Dark Brown		
TP1	6	IF0087	Domestic pottery		Brown	Grog, quartz	
IO-C	7	IF0088	Domestic pottery		Brown	Quartz	
OO-A	6	IF0089	Domestic pottery		Black	Quartz	
IO-D	3	IF0090	Domestic pottery		Brown	Quartz	
IO-B	6	IF0091	Domestic pottery		Orange	Grog, quartz	
TP2	7	IF0092	Domestic pottery		Black	Quartz	

Table 8.9: Provenience and description of the ceramic cylinders and domestic pottery analyzed with SEM-EDS

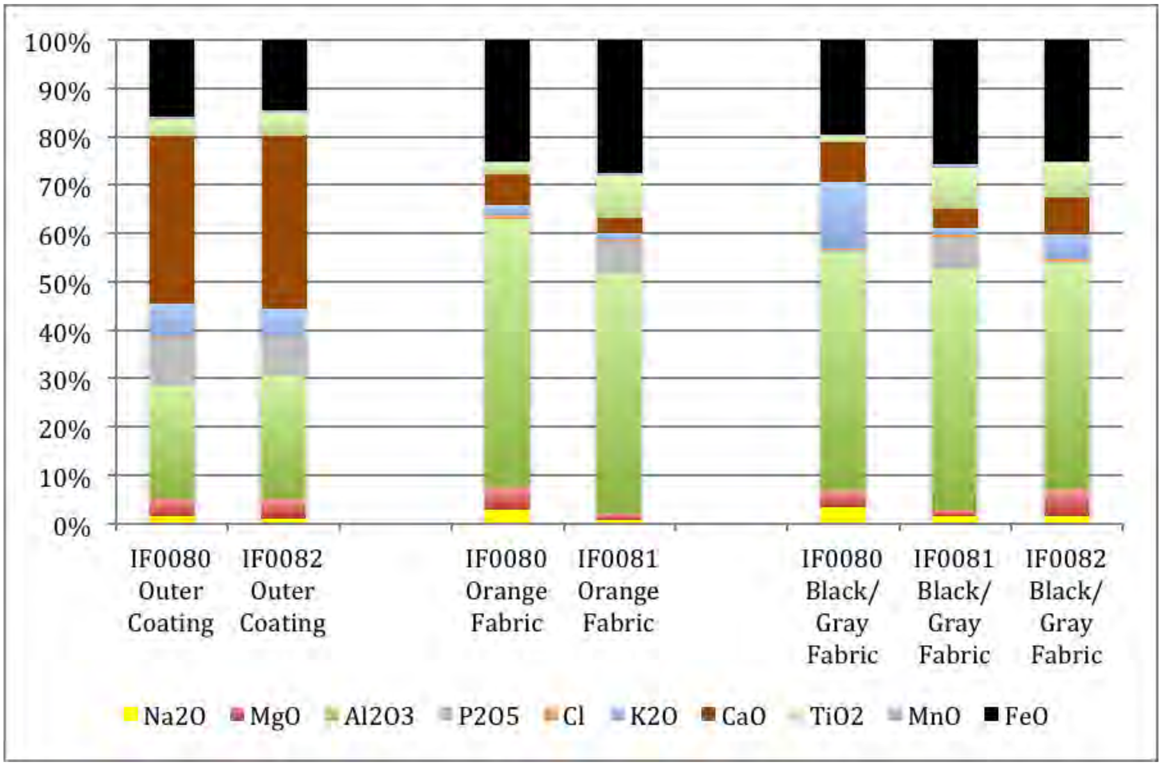


Figure 8.36: Comparative cumulative percentage frequency of the composition of the outer coating, orange fabric and black/gray fabric of the ceramic cylinders

Composition

The EDS analysis of the matrix of the ceramic cylinders reveals substantial variation between the outer coating and the fabric (Appendix E.10). The concentration of silica is lower (48%) in the outer coating compared to the ceramic fabric (up to 68%). The lower silica concentration in the outer coating is connected to low alumina. Lime concentration shows a contrast as it is higher in the outer coating (18%) and lower in the fabric (<5%). Soda is generally low in the samples (<2%). Potash and phosphorus are high in the outer coating and low in the fabric (Fig. 8.37). High potash in sample IF0080 may be considered an outlier as most of the samples have high and low P_2O_5 and K_2O in the outer coating and fabric respectively. However, the difference in the concentration of Na_2O, CaO, and TiO_2 in IF0080, may suggest that it was derived from a different clay source than the rest of the samples. This is a possiblility that needs closer attention, and perhaps analysis of more samples in the future may confirm this as a variant or suggest otherwise. The concentration of TiO_2, and FeO are consistent both in the outer coating and the fabric.

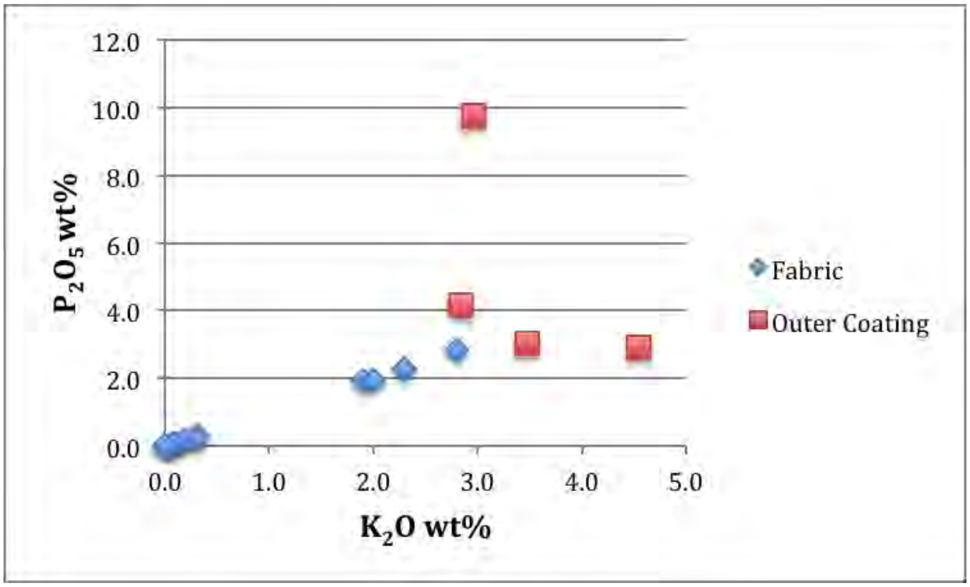


Figure 8.37: Percentage concentration of P_2O_5 and K_2O in the outer coating and the fabric of the ceramic cylinders.

Domestic Pottery

Seven domestic pot sherds were selected for preliminary compositional analysis using SEM-EDS (Appendix E.5). The samples were selected from across all the units excavated. Table 8.8 presents the provenience information of the analyzed pottery samples. Here I present the results of the SEM-EDS analysis by describing the microstruture and the composition of the samples.

SEM Analysis of Microstructure

Optical and backscatter electron microscopic study of the domestic pottery reveals a typical ceramic structure. The matrix is characterised by non-plastic materials such as crushed quartz and mica (Fig 8.38). The microscopic study confirms the initial visual recognition (with the aid of hand loupes) of these non-plastic inclusions in fresh breaks. These minerals characterize Ife pottery, which are based on the local geology (Ige *et al* 2009). Both elongated and circular voids are present in the ceramic fabric.

Composition

Results of the compositional analysis show some degree of similarity among the domestic pottery samples analyzed (Fig. 8.39, Appendix E.11). All the detected elements seem consistent in the sampled fragments with the exception of sample IF0086 (Fig. 8.39). These samples are characterized by high alumina (13%-25%) and iron oxide (6% and 11%). The high alumina and iron oxide is connected to elevated TiO_2 and Na_2O in all the samples except IF0089. This elevated Na_2O is not seen in other ceramic materials. For example, crucible fabric has NaO_2 content ranging from 0.3 to 1.3wt%, with lower concentration in ceramic cylinders (<1wt %). There is a trend of low lime (<2wt%) in the domestic pottery, as well as other clay materials. A discussion on the comparison of the compositional charateristics of domestic pottery with other clay-made material is presented below.

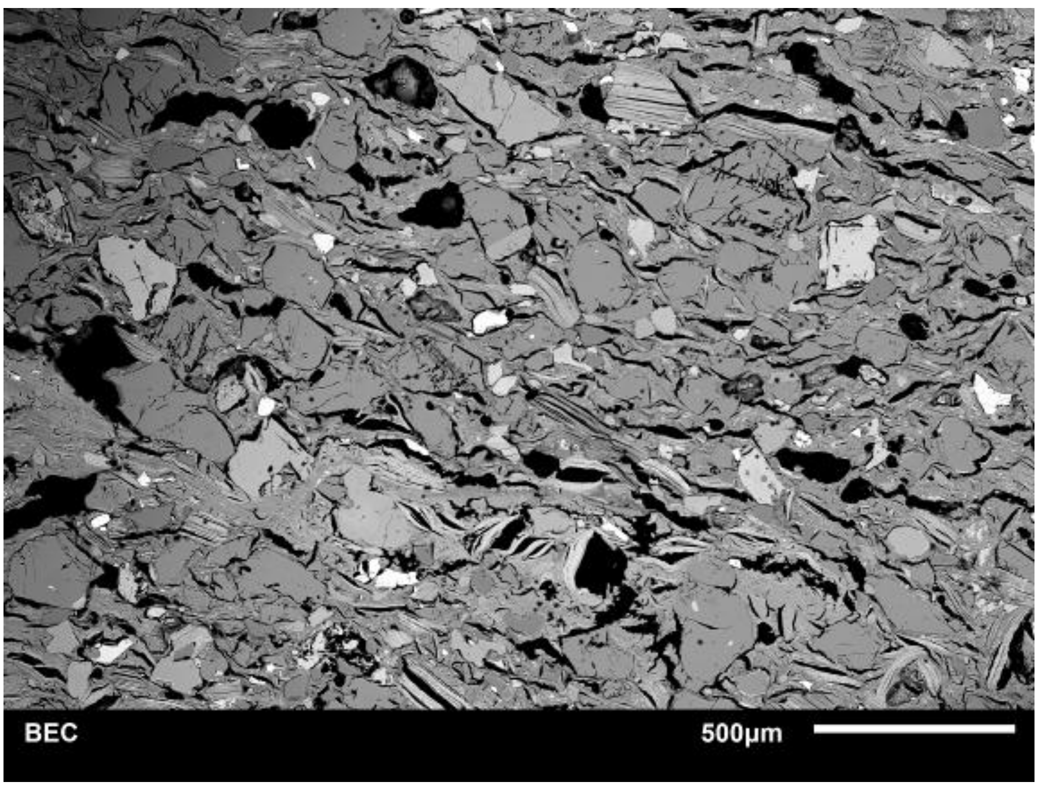


Figure 8.38. Back-scatter SEM image of the domestic pottery.

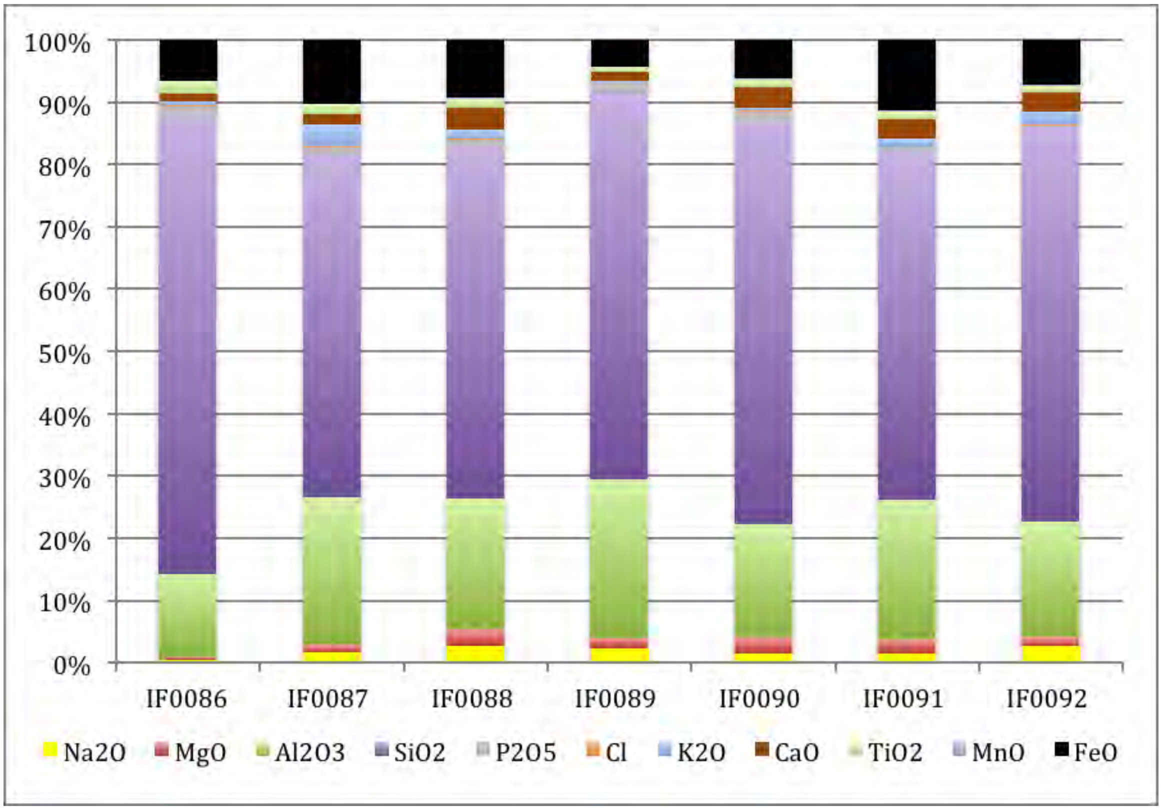


Figure 8.39: Comparative cumulative percentage frequency of the composition of the domestic pottery

Result of LA-ICP-MS Analysis of Additional Inner Crucible Glass and Other Wasters

I have already presented the result of our SEM/EDS analysis of some inner crucible glass and few wasters, mainly droplets. Here, I describe the results of the analysis of additional production-related materials by LA-ICP-MS. While previous studies of wasters from Ile-Ife have often made only gross distinctions in the glass waste recovered, this study has divided the glass debris into additional categories, including crucible glass, glass cane, droplets, and wasters (discussed fully in Chapter 7). Eight crucible glasses, ten wasters, four glass canes, and one fragment of VPD were analyzed by LA-ICP-MS. The three droplets analyzed by SEM/EDS already presented above are included in the discussion here for comparison among different production debris.

Results of the chemical compositional analysis reveal that all the wasters and most of the crucible glasses belong to the high lime, high alumina glass with concentration ranging from 10 to 17wt% CaO and 12 and 17wt% Al_2O_3 respectively (Fig.

8.40). The three droplets have extremely high lime content, while the glass canes have very low levels (Fig. 8.40). Soda and potash appear to vary significantly among all categories except the droplets, both ranging from 2 to 8wt% (Fig. 8.41).

Two groups seem to emerge when examining magnesia and phosphate levels (Fig. 8.42). The first has MgO >0.5 - <1.5wt% with P_2O_5 >0.2 - <0.7wt%. This group also has elevated copper and belongs to the major group of low lime high alumina (LLHA). All the glass canes and a few crucible glasses belong to this group. In the second group both MgO and P_2O_5 are less than 0.3wt%. Copper is significantly low or completely absent. This group shares similar characteristics with the common high lime high alumina glass (HLHA). This second group contains all the wasters and several of the crucible glass fragments. Although MgO and P_2O_5 varies between the two groups, they do not reach levels (>1.5wt%) indicative of plant ash used as alkali (Freestone 2005, 2006).

The elevated concentration of copper in the glass canes and few crucible glasses is significant for understanding the colorants used in the glass. Since all the samples with elevated copper oxide are either red or dark brown, copper could have been intentionally added as colorant.

The fragment of VPD analyzed by LA-ICP-MS is chemically similar to the samples analyzed by SEM/EDS. The content of soda is significantly low in the sample. The lime is moderate with high alumina. The concentration of MgO is high but P_2O_5 is much lower.

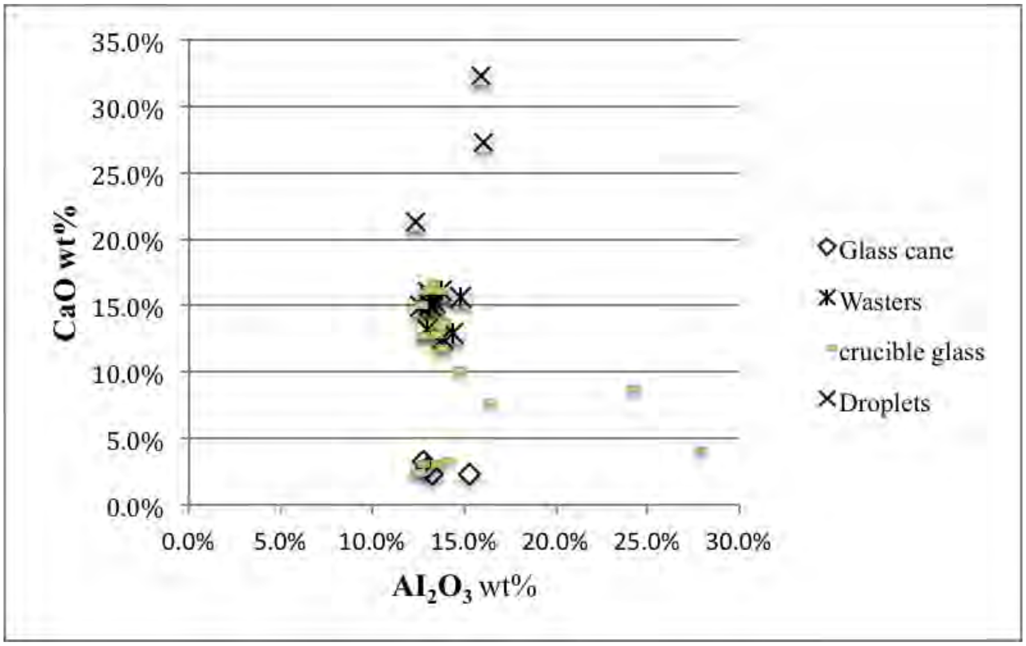


Figure 8.40: Alumina vs lime content of the production debris from Igbo Olokun by LA-ICP-MS. The droplets were analyzed by SEM/EDS

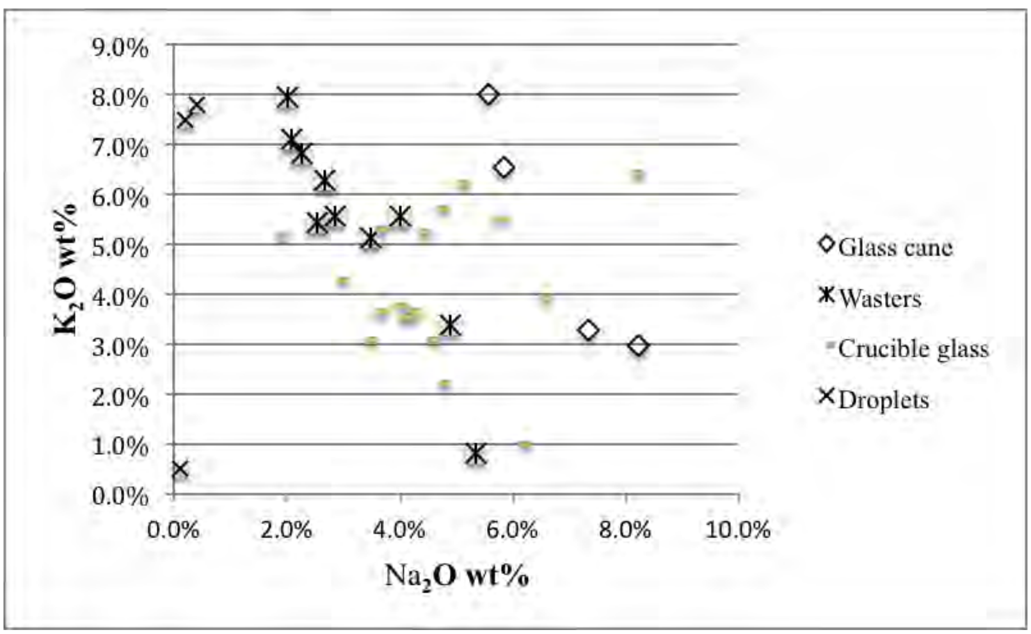


Figure 8.41: Soda vs potash content of the production debris from Igbo Olokun by LA-ICP-MS. The droplets were analyzed by SEM/EDS

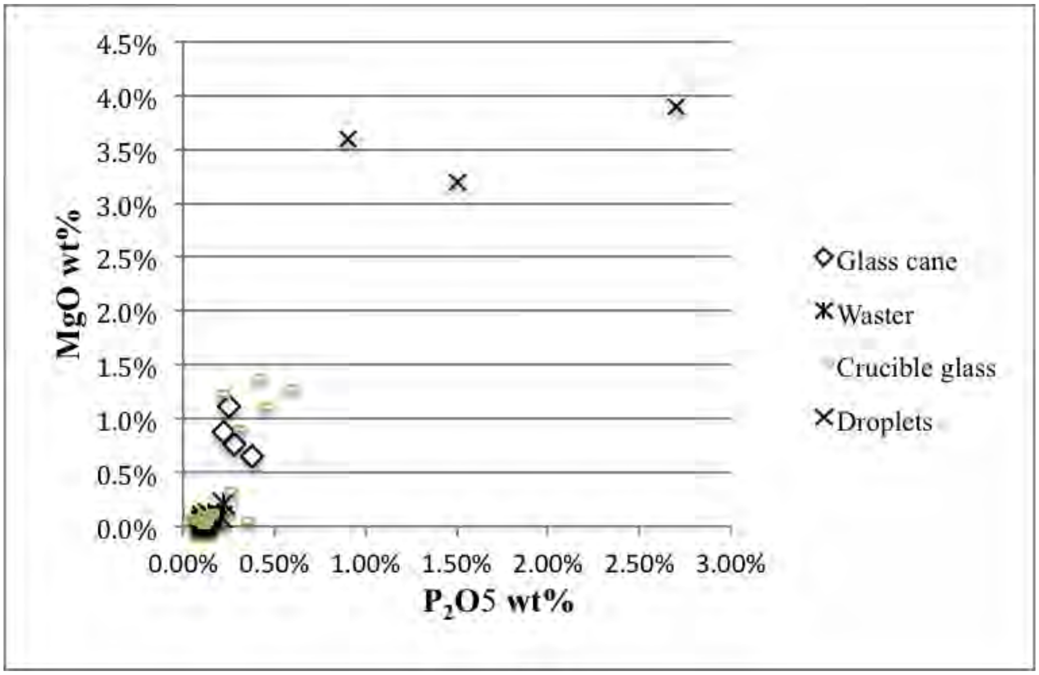


Figure 8.42: Phosphate vs magnesia content of the production debris from Igbo Olokun by LA-ICP-MS. The droplets were analyzed by SEM/EDS

Discussion

Analysis of the materials from excavations at Ile-Ife has shed light on aspects of the industrial activities at the ancient center relating to glass making and/or working. We can now offer some interpretations of the techniques and processes of production, possible sources of raw material, as well as technical and functional issues regarding the crucibles and other production materials.

Use of Crucibles in High Temperature Production

Analysis of the crucible fragments from our excavations has confirmed the use of these technical vessels in high temperature activities in Ile-Ife. The crucibles were able to withstand the temperatures of between 900 ºC and 1150 ºC, the heat needed to melt glass. They are composed of refractory kaolin clay with high alumina content, which provided good resistance to thermal shock (Ige 2010b). In fact, the more alumina content a crucible contains, the more refractory it becomes (Martinon-Torres and Rehren 2014: 15). Ige (2010b: 9) suggests that the locally abundant kaolin clays with high alumina content (>20%) could have proved a good clay source for the Ile-Ife crucibles. Crushed quartz and/or organic materials may have been added as temper to the crucible clay to enhance its resistance to thermal shock when used in high temperature furnaces. The vitrification of the outer layer of crucible fabric attests to the high temperature sustained by the crucible fabric, and the presence of some fluxing agent to vitrify the surface. Similarly, cracks in some of the crucible fragments also point to intense heat. The glass seepage observed in some of the cracks suggests that the crucible must have cracked with glass melt inside, perhaps while in the furnace.

In addition, the high concentration of lime, magnesia, potash and phosphorus oxide in the composition of the outer glassy coating is a strong indication of contamination from fuel ash resulting from the high temperature (Rehren 1997: 357). (Fig. 8.43). There are some samples with low lime content and these may indicate that they were in the furnace for shorter periods of time. Consequently, they accumulated less calcium oxide from the fuel ash. This idea is further supported by the composition of the droplet samples analyzed. The high concentration of magnesia, potash, phosphorus, and calcium oxides with corresponding low soda content is also observed in the samples of droplets analyzed, which show that the droplets must have dripped from the crucible surface due to intense heat. In addition, the extremely high lime content suggests that they must have stayed for a long time in the furnace for the lime to accumulate.

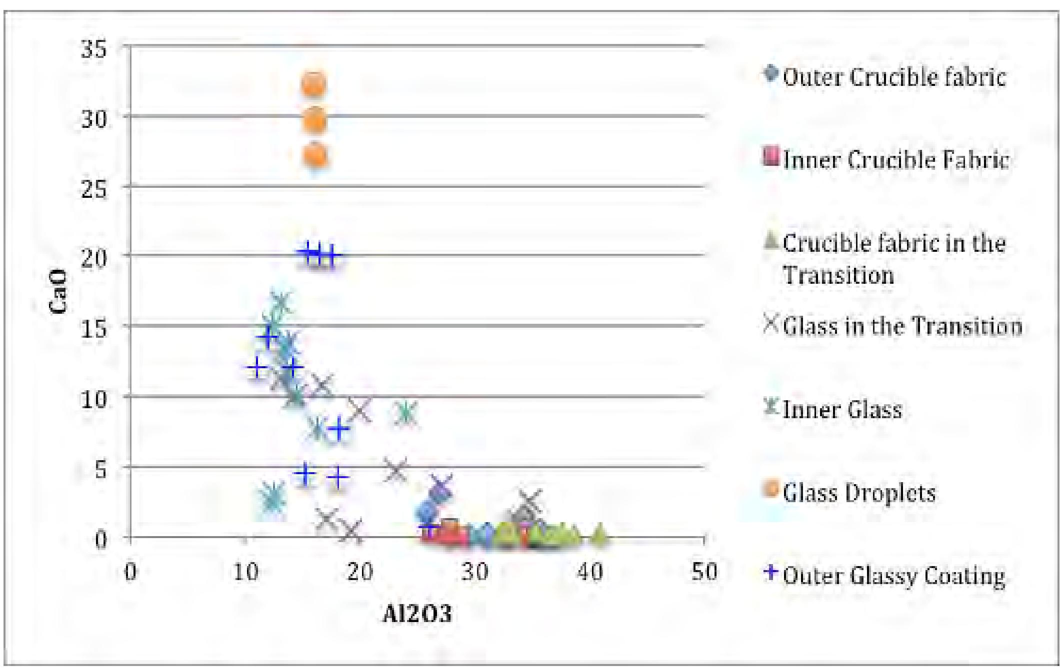


Figure 8.43. Comparative percentage concentration of Al_2O_3 and CaO in crucible fabric, inner glass, and glass droplets.

The crucible morphology appears to have served a functional purpose. Crucible thickness of between 2cm and 4cm and a restricted orifice were designed to provide mechanical stability and to contain the heat in the crucible, respectively.

The results of the analysis here potentially show that some form of primary production took place at or near the site, based primarily on the presence of quartz grains in the matrix of the inner glass (Fig.8.17). Given the distance of the quartz grain from the crucible fabric, it is unlikely that the quartz grains migrated from the crucible clay into the inner glass matrix. Similarly, the quartz grains could not have penetrated the inner surface into the matrix after deposition. Thus, the explanation that best accounts for this is that the quartz grains are residue from unmelted siliceous raw material for glass that was fed into the crucible at a particular stage of production. As the quartz grains were only observed in 30% of the samples analyzed, it is possible that some selected crucibles were used for primary glass production. If this was the case, the attributes that may have made the crucibles for primary glass production different from other glass working crucibles are worth investigating. Further microscopic and chemical analysis of more crucible samples may help to provide necessary information as well as help to clarify the interpretation of primary glass production in Ile-Ife.

But melting of raw material for glass in primary production is not the only process that could account for the presence of quartz grains in the crucible matrix. Frit or semi-finished glass is characterized, in part, by some quartz grains in the matrix (see chapter 3 for discussion on the process and purpose of fritting). Saleh et al. (1972: 164) have suggested that the processes of glass making do not necessarily have to start and finish in a single workshop or location. In fact frits or semi-finished glass were exported to glass working studios where they were remelted, with or without additional ingredients such as flux or colorants. If quartz grains are preserved in frit or semi-finished glass, they could still be preserved even when the final glass is made. In such a situation, one would expect that the major elements of the glass from the glass-working studio resemble that of the primary glass-making center. As Lankton *et al.* (2006) and Freestone (2006) have noted, the uniqueness of the Ile-Ife HLHA alumina glass among the known compositional groups from the old world suggests a local recipe. Primary production may have taken place in or near Ile-Ife but not necessarily at Igbo Olokun. Perhaps Igbo Olokun was mainly a glass-working workshop.

The presence of colorants in form of swirls or *schlieren* in the glass matrix is additional evidence that crucibles were used in primary glass making and secondary glass working (Rehren *et al* 2012: 82). These swirls (e.g. sample IF0074 – Fig. 8.17) can indicate incomplete mixing of colorants. Rehren *et al* (2012: 82) have suggested two conditions that may lead to incomplete mixing: the first is an intentional attempt by the glassworker to avoid stirring the glass close to the bottom of the crucible in order to prevent cracking that can occur from hitting the crucible wall; the second is an incomplete melting before the process was interrupted by the craftsmen for unknown reasons.

Furthermore, the presence of multiple colors (or shades of the same color) in the inner glass of the crucible may have resulted from the reaction of colorant oxides under different furnace conditions (Goffer 2007). For example, the presence of copper oxide in a glass batch gives a blue color in oxidizing conditions and red under reducing conditions. Similarly, iron oxide in glass melt under reducing conditions can result in either black or green glass (Table 3.1).

Figure 8.6 illustrates crucible fragments with multiple colors in the inner glass. Whether the multiple colors found in a few of the crucibles resulted from improper mixing or furnace conditions, it suggests that colorants were being added into the glass melt in ancient Ile-Ife. Although it is unclear when exactly colorants were added during the glass production process (Smirniou and Rehren 2011: 60), it can be assumed that colorants were added at the early stage of glass making in Ife, since it would be technically difficult to re-melt uncolored glass at higher temperatures (between 900 ºC and 1000 ºC) in order to add colorants (Smirniou and Rehren 2011: 76).

Ceramic Cylinders and Glass Working

In considering the possible function of the ceramic cylinders, the fact that they were not as vitrified as the outer crucibles surface raises the question of whether or not they were used directly in high temperature activities. The initial proposition that ceramic cylinders were rods used to tilt or otherwise maneuver the crucibles when they were hot and filled with molten glass (Babalola, 2012), or as handles for lifting the lids (Willett 2004), may need further consideration, as the strength of the ceramic cylinders is not likely to support the size and weight of most of the crucibles. Also, the outer whitish-gray coating on the ceramic cylinders and the evidence of oxidation on one side reveal that they were used in firing activities but not necessarily glass making/working. If the ceramic cylinders were used directly in glass working furnaces it would be expected that they would have been vitrified and turned black because of their high iron oxide content.

One alternative is that they were used in another craft production process, possibly in the production of pottery. For example, Pohl *et al* (2012: 59) have reported the occurrence of similar materials in a production context at the 13th- and 14th-century site of Karakorum in Mongolia. They argue that the artifacts are comparable with finds in a kiln site at Orkhon Valley, and that they were used as clay supports in pottery production. The whitish coating on the ceramic cylinders is consistent with them being used in some high temperature activity, but not necessarily as pottery kiln furniture. Since kiln firing of pottery is not common in Yorubaland, it is difficult to interpret the ceramic cylinders as kiln furniture. Although pottery and glass making as well as other craft production are known to co-exist elsewhere (e.g. Nicholson 2000), there is no convincing evidence for this at Igbo Olokun. Further typological and contextual investigation rather then chemical characterization with more fieldwork in the vicinity will shed more light on the interpretation of this class of material.

Vitrified Production Debris (VPD)

The degree of vitrification of VPD indicates exposure to high heat, but compositional analysis indicates that the material was not used as raw material for glass making at Ile-Ife. In comparison with typical Ife glass, the material has a lower concentration of alkalis (soda and potash), and relatively high magnesium and phosphorus oxides. High concentrations of magnesium and phosphorus oxide are not generally characteristic of glass and may have resulted from contamination from fuel ash rather than properties of glass raw material. Additionally, the black areas, rich in titanium and iron oxide, have no chemical similarity with the Ife glass but are more similar to ordinary clay. This evidence suggests that the VPD was not raw material for glass in classical Ife.

It may be possible that the VPD represents degraded furnace remains. The VPD is dark-brown and/or black in appearance with a high Al_2O_3 indicating a clay basis. Elevated titanium and phosphorus oxides may represent contamination by "black sand" from Ile-Ife (Ige and Rehren 2003: 19).

Elsewhere, amorphous partially vitrified material similar to the VPD has been found to be associated with iron smelting furnaces (Crew and Rehren 2002; Crew 2000). This is not to suggest that the VPD from Ile-Ife were also remnants of iron smelting furnaces. But since both iron smelting and glass making require intense firing, the reaction of the furnace clay to the heat could be comparable. The occurrence of a white layer adhering to the matrix of the VPD (black area) is of interest; this white area may represent a phase in repairing of the furnace (Crew and Rehren 2002: 85). When new clay is added to any part of an existing furnace there is the possibility that fuel ash would have built up on the surface of the furnace. This layer of fuel ash coating, when fired over several times, will continue to melt into the matrix, and thus form a layer. The high concentration of CaO in the white area compared to the black area suggests that lime may have come from fuel ash. This interpretation will be further tested perhaps with follow-up experimental work in the future.

Comparing Crucible Clay with Other Clay Materials

Compositional analysis demonstrates high alumina content characterizes all the materials, ranging from 12% to 35% covering the full spectrum of low and high for clay materials. While ceramic cylinders and domestic pottery have alumina ranging from 12 to 25wt%, crucibles appear to have very high content exceeding 25wt% (Fig. 8.44). Recent chemical characterization of pottery from potsherd pavements in and around Ile-Ife has also generated data that show the concentration of alumina between 15% and 17% (Ige and Ogunfolakan 2009). Iron content is also varied among the clay materials. While iron oxide concentration is high in other clay materials, it is low in crucibles.

The variance between the crucible clay and other clay materials points to different refractoriness of the different clays and the craftsmen's choice of the materials. If the crucibles were fired in the same furnaces where the VPD is part of the furnace wall (possibly the inside lining), it is interesting to note that the VPD is fully melted, while the crucible is vitrified, but not molten. This reflects that the same temperature has different effects on the different clays. The inner furnace wall was 'allowed' to soften and melt since the thick wall and its outer structure would have kept the furnace intact, while the crucible had to transmit the heat from the outside to the inside of the crucible in order to melt the glass, and retain the structural integrity of the crucible. This shows that the craftsmen had a clear understanding of the clay properties required for each task.

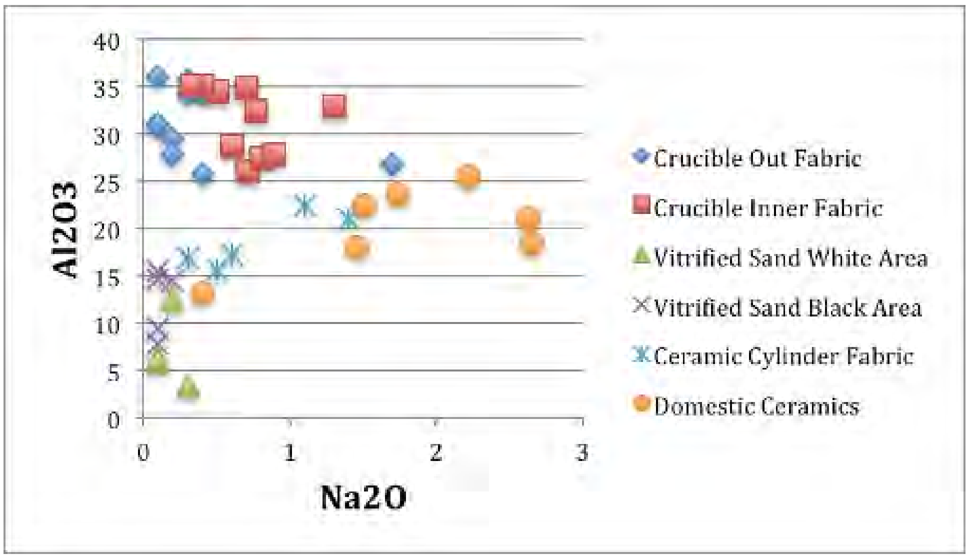


Figure 8.44. Comparative percentage concentration of Al_2O_3 and Na_2O in all the ceramic materials.

Comparing and contrasting the SEM-EDS data show that there is a relationship among the outer glassy coating of the crucible, outer coating of the ceramic cylinders, and the white area of the VPD. In all these materials, these areas have high concentrations of magnesia, phosphorus, potash, and lime. As discussed above, this suggests similar sources of contamination (fuel ash). However, the variation in these fuel ash oxides concentrations may suggest differences in intensity and frequency of heating. For instance, the very high potash, and to a lesser extent, lime content in the outer glassy coating of the crucible may indicate intense and frequent heating and exposure to furnace gases, while the relatively low concentration in the outer coating of the ceramic cylinder and VPD may suggest less frequent heating, and perhaps less contact with fuel ash (Yin *et al* 2011; Rehren and Yin 2012). The pertinent question therefore is that to what extent these materials are related to glass making/working activities at Igbo Olokun.

Summary of the analyses

The SEM-EDS analysis of the crucibles and other high temperature materials from Ile-Ife has opened a pathway for understanding some technical and functional aspects of glassmaking and glass working in early Ile-Ife. Despite the lack of direct evidence of primary production such as furnace structures or raw/semi-finished glass, the data at present are not inconsistent with glassmaking and certainly demonstrate glass working on site. The chemical composition of production debris including crucible glass and wasters from our excavations is consistent with the high alumina signature that Lankton *et al*. (2006) propose was locally produced. The corresponding high alumina content in the domestic pottery and crucible fabric also supports the argument that high alumina is characteristic of local raw material. We have pointed to the presence of quartz grains and the swirling of colorant in the crucible glass matrix as possible indicators of primary glass production. The variation in the lime content may reflect the varying amounts of snail shell – proposed by Ige *et al* (under review) as the source of the lime – added to the glass mixture. The forms, quantity, and context of the production debris indicate industrial rather than household based production in Igbo Olokun. The absence of frit or semi-finished glass supports an interpretation of complete rather than partial batch production.

In the final section of this chapter, I compare the crucibles and other production debris recovered from sites in and around Ife with the Igbo Olokun material. Questions of interest include the range of variability present in glass composition, crucible form and fabric, and production processes.

Glassworking Debris from other sites in and around Ile-Ife

> *"Martius picked up a couple of bits …. wiped the dust off one of them … glaze! We examined the other one – glaze again! … the body of them all was a substance like porcelain clay, similar to cement, but they were all coated with glaze of many colors. Afterwards, we found entire jars, with*

lids belonging to them, glazed both inside and out …" (Frobenius, 1968 [1913]: 93)

Frobenius provided the first descriptions of crucibles in Ile-Ife, found during his 1910 expedition. It is clear that he found some whole crucibles, but he does not state the number. Rather than describing individual crucibles, he gives a general view of the whole assemblage, including the range of inner and outer glass colors, and the range of sizes (see Table 8.10). Willett's (2004) catalogue on Ile-Ife illustrates and describes complete and near complete crucibles from his excavations at Ita Yemoo and Olokun Grove, as well as crucibles found at other sites around Ile-Ife both by local people and other researchers (Table 8.10). The limited descriptions correspond well with the Igbo Olokun crucibles.

The important work of Lankton *et al* (2006), which I have discussed in detail, provides us with the platform necessary for microstructural comparison of Ile-Ife crucibles. In this research, two crucible fragments from the collection of the Natural History Museum, Ile-Ife were analyzed by light and electron microscope. Unfortunately, the contextual details of the samples are unknown; they are described as coming from Ile-Ife and may have been collected from the surface at Igbo Olokun. All the physical attributes recorded on the samples match the assemblage from Igbo Olokun (Lankton *et al* 2006: 116).

Site	ID #	Height mm.	Shape	Inner glass	Outer Glaze/Glass	[c]Additional Notes
[a]Olokun grove		356-610	Ovoid	Light green, greenish white, dark red, brown, and blue	Light green, greenish white, dark red, brown, and blue	Maximum shoulder diameter: 254–406 mm; rim diameter small; Thickness: 18–31 mm;
Ita Yemoo	828	165	Barrel	?	Thin outer glaze	Scrape marks inside. A string of beads was inside
Itajero, Ilode	829	330	Conical-Oval	Dark Red	Matte buff	Rough outer surface
	830	311	Elongated Ovoid	Transparent pale green	Dark green	Broken rim
Olokun grove	831	316	Oval	Light blue	?	Red glass on the neck. Apparent lid ridge
Igbinbin	832	187	Barrel	Green	Deep Red	Very thick outside coating
Iremo	833	222	Barrel	?	Blue	Busted on the body, with thick outside coating
?	834	185	Cylindrical	Blue	Matte greenish-blue	Heavy outside coating with boss of glass on the bottom
[b]Olokun grove+	835	355	Conical-Oval	Transparent pale greenish-blue	Green/matte buff	Diameter: 305; Inside depth: 316; Base thickness: 39. Deeply cracked
	836	?	?	?	?	Thick-walled. Fragment of a flat-bottomed crucible

Table 8.10: Description of Ile-Ife crucibles by Frobenius (1913 - Olokun Grove) and Willett (2004). [a] = The information is based on Frobenius' sum of the crucibles characteristics. Count and individual data not provided. [b] = Willett states that they were dug up for Frobenius. [c] = Except otherwise stated, diameter and thickness information are not provided. ? = The data is not provided.

The microscopic analysis performed by Lankton *et al* (2006: 119) noted the following:

- uniform moderate vitrification of the paste throughout the samples with presence of large amounts of fine quartz particles, scattered and ruptured, resulting from heating
- few inclusions of iron and titanium oxides in the paste
- pores in the crucible fabrics were partly to fully rounded
- voids were typically elongated more-or-less parallel to the outer surfaces of the crucibles; this may represent evidence of organic material in the clay mixture
- vitrified areas within the ceramic, rich in soda

Comparison of the composition of the crucibles studied by Lankton *et al*. and those from Igbo Olokun indicates some similarities and differences. The highly refractory nature of the crucibles is reflected in very high alumina content with other minor oxides lower than the usual concentrations in glass. Although the concentration of iron is slightly elevated in about half of the Igbo Olokun crucible samples, it is in same range with those reported in Lankton *et al* (2006). Similarly, both assemblages contain vitrified areas within the crucible fabric rich in soda.

The difference between the two sets of data is more procedural than compositional. As stated above, we employed a procedure that analyzed the crucible fabric in profile; that is, we were interested in seeing compositional differences between different areas of the crucible fabric. For example, we examined how the outer coating may be similar or different from the adjacent fabric, the core area, and core area to the inner area closer to the interior glass. This process revealed significant contrasts between the fabric areas close to the outer coating and the interior glass, as they tend to show a composition similar to the outer coating and interior glass respectively rather then the core fabric. This distinction helps us to better understand how chemicals leach from the fabric to the glass and vice-versa, particularly at the transition zone. Since Lankton *et al* (2006) only examined the core of the fabric; possible comparisons in this regard are constrained.

Outside of Ile-Ife, only one glass-related crucible has been described. Ogundiran (2014) describes a crucible fragment from the 17th–19th century site of Osogbo as "covered with translucent pale green glass of uneven thickness, while the interior encrusted with green glass." Beyond Yorubaland, there are no other crucibles related to glass production reported. Crucibles related to other forms of production—for working alloys such as copper and gold—have been recovered from 8th- to 12th-century sites in West Africa (e.g. Nixon 2009; Cisse *et al* 2013). Archaeological finds of glass making crucibles are thus far restricted to the Ile-Ife area.

Crucible glass, cullet, and wasters compared

Ile Ife sites

Davison (1972) analyzed eleven crucible glass fragments: two from Olokun Grove and nine from Ita Yemoo. Additionally, she analyzed 12 cullet fragments: five from Olokun Grove and seven from Ita Yemoo. She also included two samples that she called 'sherds,' but she did not say how they are similar to, or different from, cullet. One of the 'sherds' came from Olokun Grove; the second sample was from Ife but it is not clear from which site it came.

Davison identified three debris groups. Group I corresponds with HLHA glass and appears to be the dominant group in her assemblage, present both in the crucible glass and cullet from Ita Yemoo and Olokun Grove (Fig. 8.45). Since Davison did not record lime for her group II artifacts, it is not possible to compare these materials with the Igbo Olokun artifacts, and I have thus excluded them to from discussion. However, two of the three samples in the group seem to have low alumina, and one with higher values. There are only two samples belonging to group III and both are called 'sherds;' both high lime, low alumina glass. The soda and potash concentrations vary significantly (Fig. 8.46). The soda varies between 1.8 and 7 wt% among the group I artifacts. One sample of group III also falls in this range. Another sample of group III has extremely high soda content, which makes it a soda-lime glass group. Potash varies from <1 to <9wt%. No site specific or material category based variation is noticeable in the soda and potash concentration.

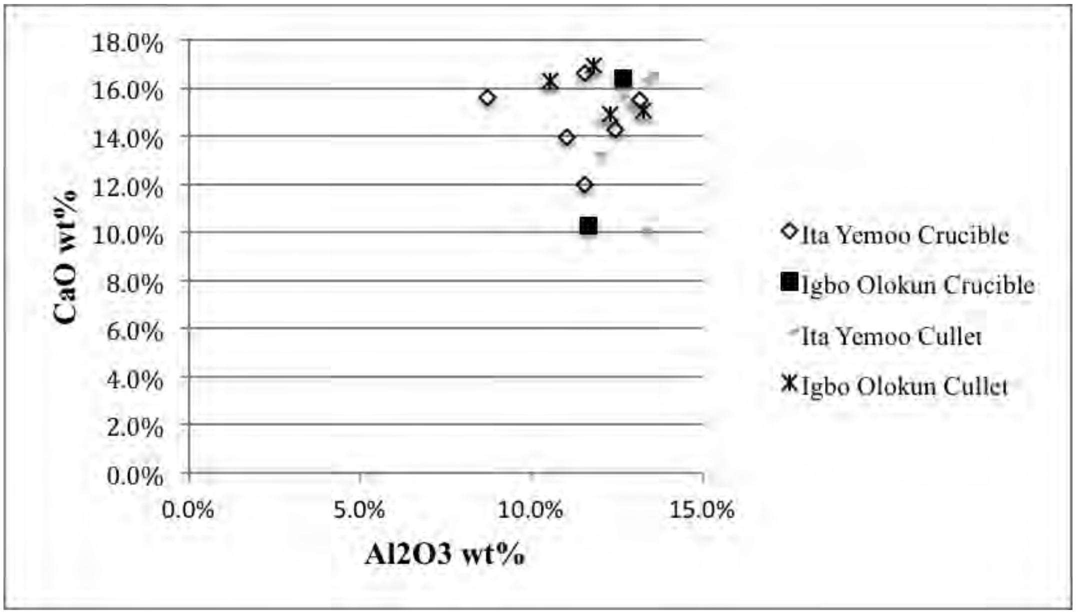


Figure 8.45: Alumina vs lime content of Davison's cullet and crucible glass from Ile-Ife
N.B.: Because Davison did not record lime content for Group II, it was excluded from this chart.

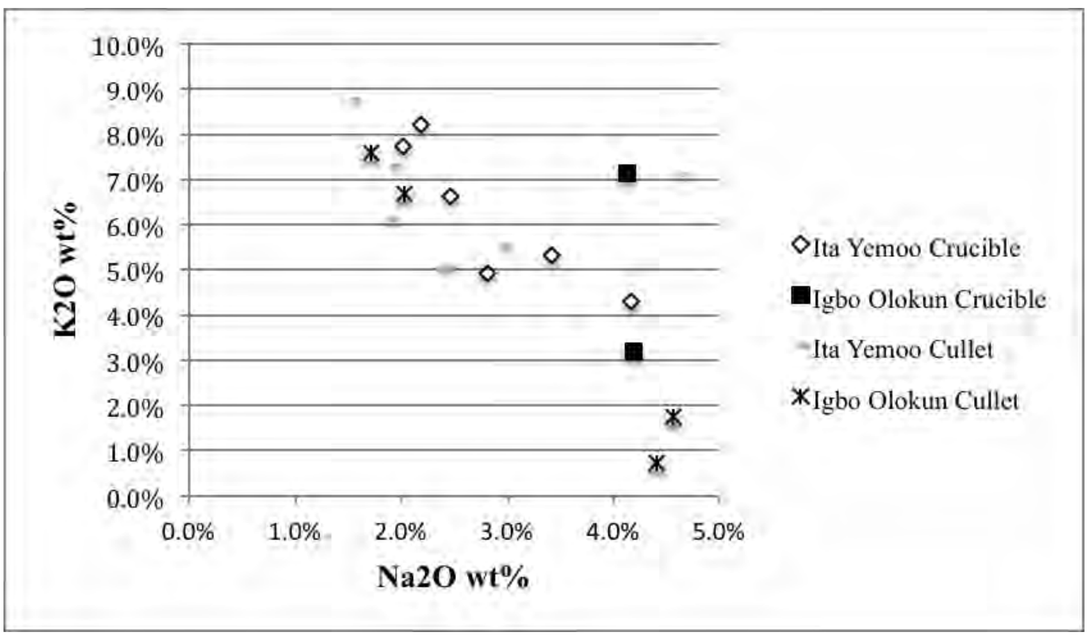


Figure 8.46: Soda vs potash content of Davison's cullet and crucible glass from Ile-Ife.
N.B.: Because Davison did not record potash content for Group II, it was excluded from this chart.

Whereas Davison's (1972) data provide comparative data for only one class of glass – HLHA – Lankton *et al's* (2006) data show both high and low alumina glass. Lankton *et al* (2006) analyzed inner glass in two crucibles, 24 cullet fragments from *aje ileke* 1, seven from *aje ileke* 2, and one from *aje ileke* 3. The source and nature of the samples have been discussed above. The results of this analysis indicates that HLHA glass dominates the assemblage: the glass in the two crucible fragments belong to this group (Fig. 8.47), as do 13 cullet fragments from *aje ileke* 1 and 1 from *aje ileke* 2. Eleven cullet fragments from *aje ileke* 1 belong to low alumina (<8wt%) and high lime (>10wt%) group. A single cullet sample from *aje ileke* 3 and 4 samples from *aje ileke* 2 are low in both lime and alumina. Those with low lime low alumina are rich in soda, which places them in soda-lime glass group. Overall, soda and potash vary significantly. However, three patterns can be observed in this assemblage (Fig. 8.48): First, there are only a few crucible glass fragments with low soda (<0.2wt%), high potash (7-9wt%). Second, there is a broad range of soda from 3-<10wt%, and potash from 0 - <6wt% in the assemblage. Finally, soda-lime glass with soda >10wt% and low potash (<3wt%) is common. Figure 8.49 shows the concentration of phosphate and magnesia in the samples. While the content of phosphate is low (<1.2wt%) in both the crucible glass and cullet, magnesia levels vary significantly ranging from 0 to <2.5 wt% in *aje ileke* 2 & 3 and some of *aje ileke* 1. All the crucible glass along with a few cullet samples from *aje ileke* 1 have elevated magnesia (>2wt%).

Comparison of the Igbo Olokun assemblage with Davison (1972) and Lankton (2006) reveals the homogeneity of the HLHA group (Fig. 8.50). The content of lime and alumina in Igbo Olokun crucible glass and wasters are similar to the crucible glass and cullet from Ita Yemoo and Olokun Grove. Additionally, the crucible glass and cullet from *aje ileke* 1 is similar to those from Igbo Olokun. The LLHA appears to be limited to Igbo Olokun, represented by unperforated glass canes and a few crucible glass fragments. Soda and potash concentrations in the Igbo Olokun crucible glass and waster material seem to be similar with < 9wt% for both oxides. These values are also found in the samples from Ita Yemoo, Olokun Grove, as well as many of the samples studied by Lankton *et al.* (2006). The only exception can be found in the *aje ileke* 2 and 3 materials that have elevated soda levels (Lankton *et al.* 2006). These samples with high soda are soda-lime glass, and therefore likely to have originated from the Mediterranean or Middle East.

To compare magnesia and phosphate, we are limited to samples from Lankton *et al.* (2006) and those from Igbo Olokun, since Davison did not record these oxides. The Igbo Olokun samples have MgO <1.5 wt% and P_2O_5 <0.7wt%. The concentration of the crucible glass and wasters from Igbo Olokun would be considered elevated in comparison to those analyzed by Lankton *et al.* (2006), although their cullet samples are still within the same range (<1.5wt%) that suggest that plant ash was not used for the alkalis.

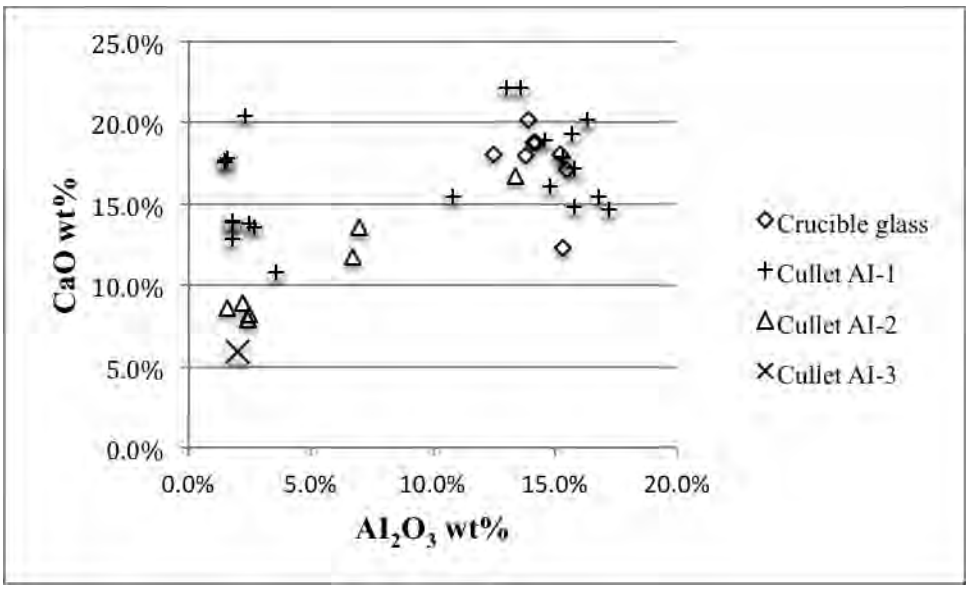


Figure 8.47: Alumina vs lime content of Ile-Ife crucible glass and cullet from *aje ileke* analyzed by Lankton *et al.* (2006).

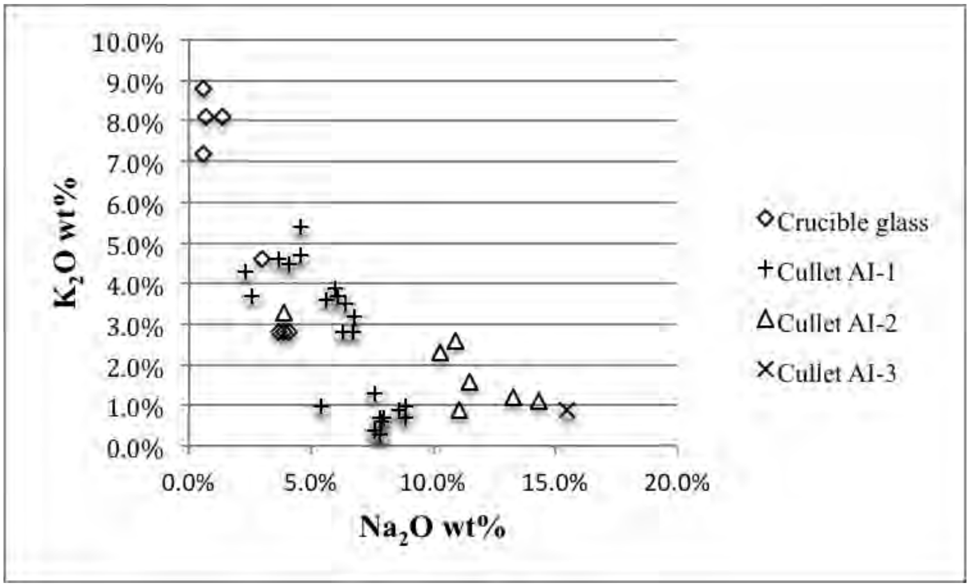


Figure 8.48: Soda vs potash content of Ile-Ife crucible glass and cullet from *aje ileke* analyzed by Lankton *et al.* (2006).

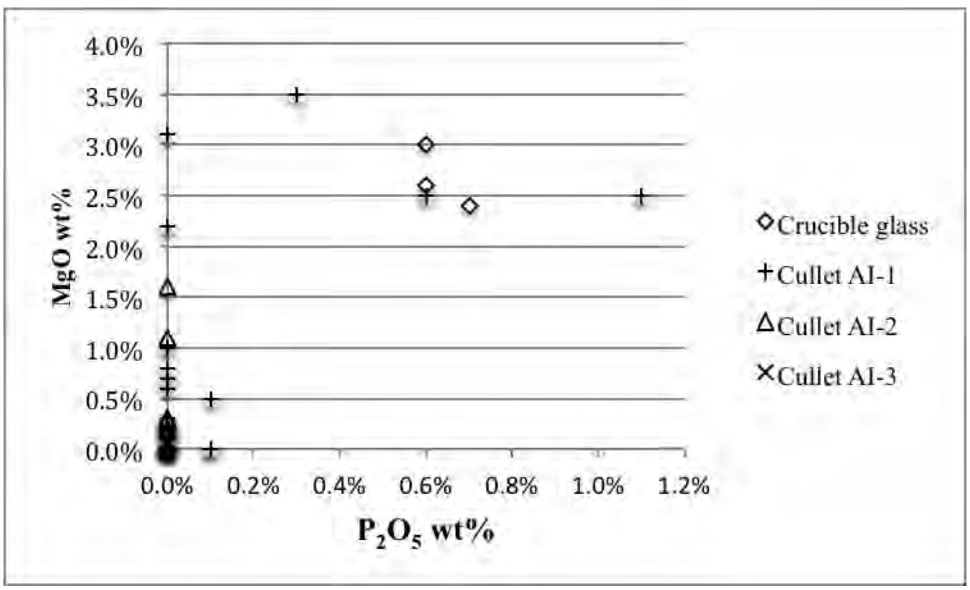


Figure 8.49: Phosphate vs magnesia content of Ile-Ife crucible glass and cullet from *aje ileke* analyzed by Lankton *et al.* (2006).

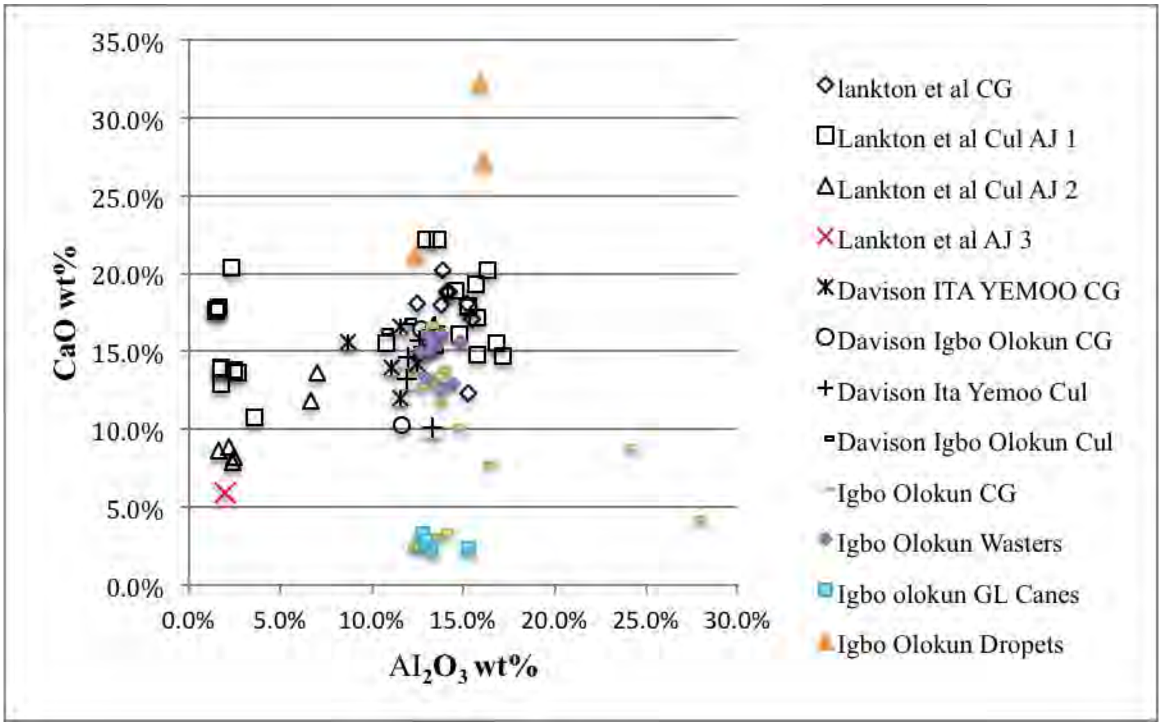


Figure. 8.50: Alumina vs. lime content of Ile-Ife production debris. CG = crucible glass; Cul = cullet.

Osogbo

The data from Osogbo site are the only ones available from outside of Ile-Ife in Yorubaland, where Ige *et al.* (under review) chemically analyzed 26 cullet samples by LA-ICP-MS. The analysis was carried out along with other glass beads already discussed (in Chapter 7). Because no crucible glass was analyzed, I compare the cullet from Osogbo to the wasters (including the glass canes and droplets) from Igbo Olokun.

Most, if not all, of the cullet from Osogbo is HLHA glass (Fig. 8.51). This means that both alumina and lime are >10wt%, although there is one case of low lime high alumina. Soda and potash vary significantly, ranging from 1–7 wt% and 1–9 wt%, respectively (Fig 8.52). Concentrations of magnesia and phosphate are both <1.4 wt%. In fact, phosphate is much lower, not exceeding 0.7 wt% (Fig. 8.53). Comparison of the Igbo Olokun debris with cullet from Osogbo demonstrates that this material belongs to the HLHA group (Fig. 8.54). The soda and potash contents, although slightly varying, fall within the same pattern seen in Igbo Olokun materials (Fig. 8.55). Similarly, the phosphate and magnesium content of the Osogbo waste match the debris from Igbo

Olokun (Fig. 8.56). The extremely high lime, magnesium, and phosphate with low soda concentration in the droplets from Igbo Olokun differs significantly from the rest of the glass objects and wasters (Figs 8.4, 8.5, & 8.6). These differences are testament to the fact that the droplets are heavily contaminated with fuel ash – a process that is expected in glass working workshop as well as glass making factory.

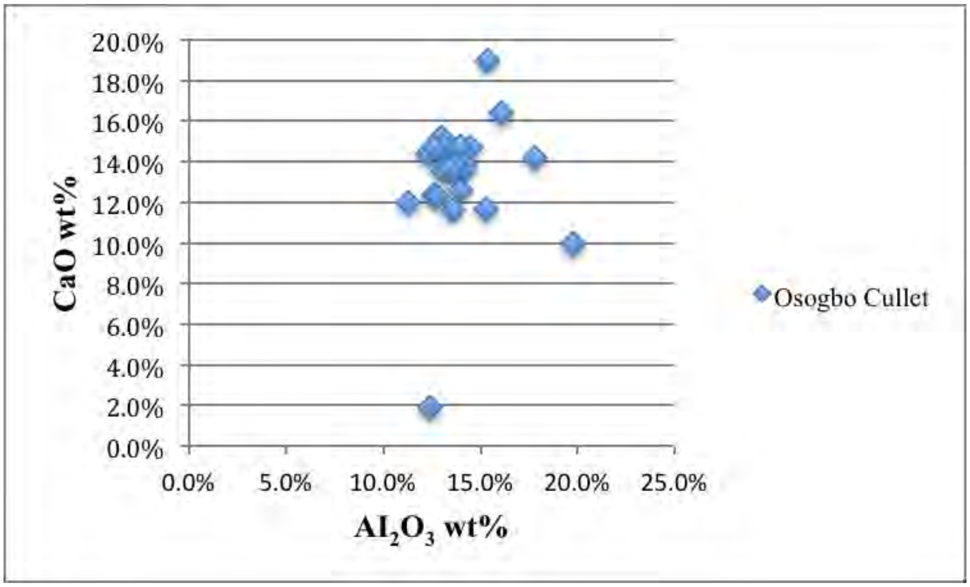


Figure. 8.51: Alumina vs. lime content of Osogbo cullet showing the clustering of the HLHA group (Data from Ige *et al.* under review).

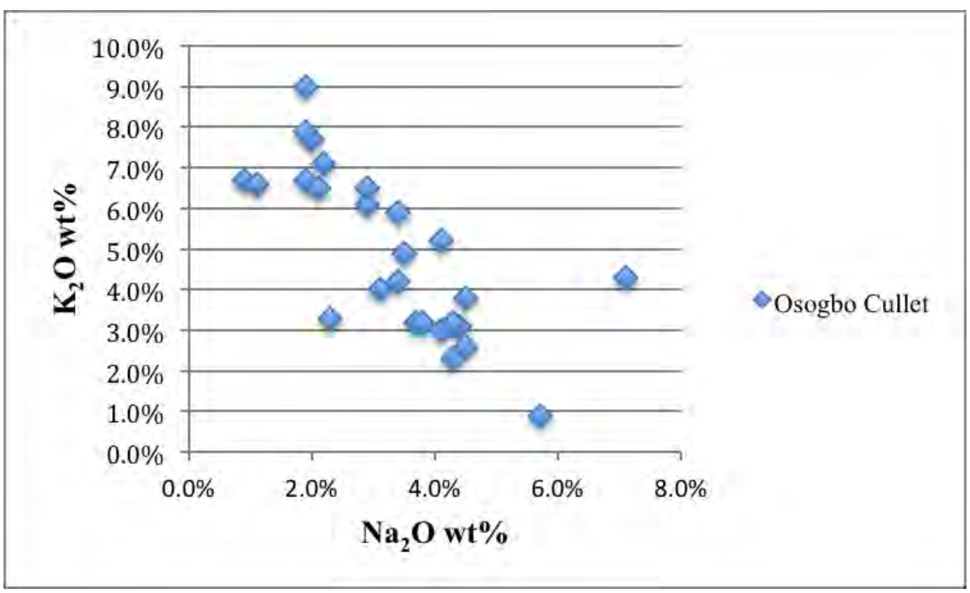


Figure. 8. 52. Soda vs. potash content of Osogbo cullet (Data from Ige *et al.* under review).

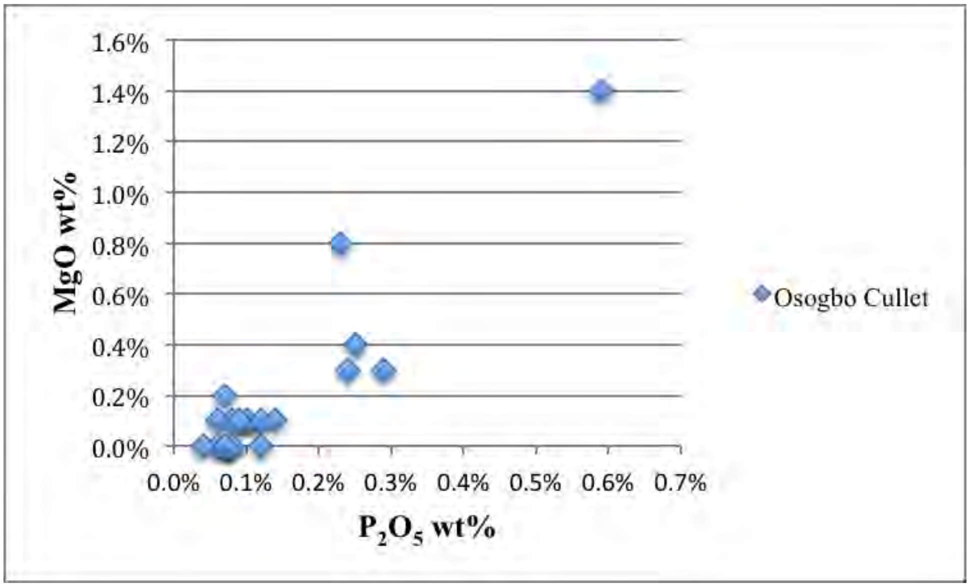


Figure. 8.53: Low phosphate vs magnesia content of Osogbo cullet (Data from Ige *et al.* under review).

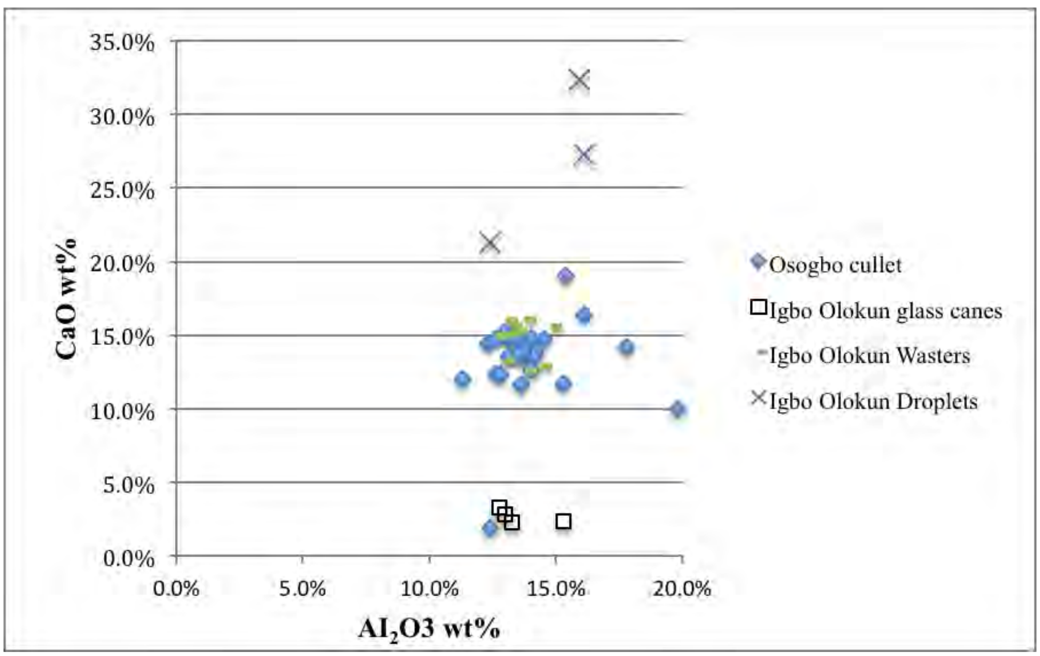


Figure. 8.54: Comparison of alumina vs. lime content of Igbo Olokun debris with Osogbo cullet showing HLHA and LLHA groups.

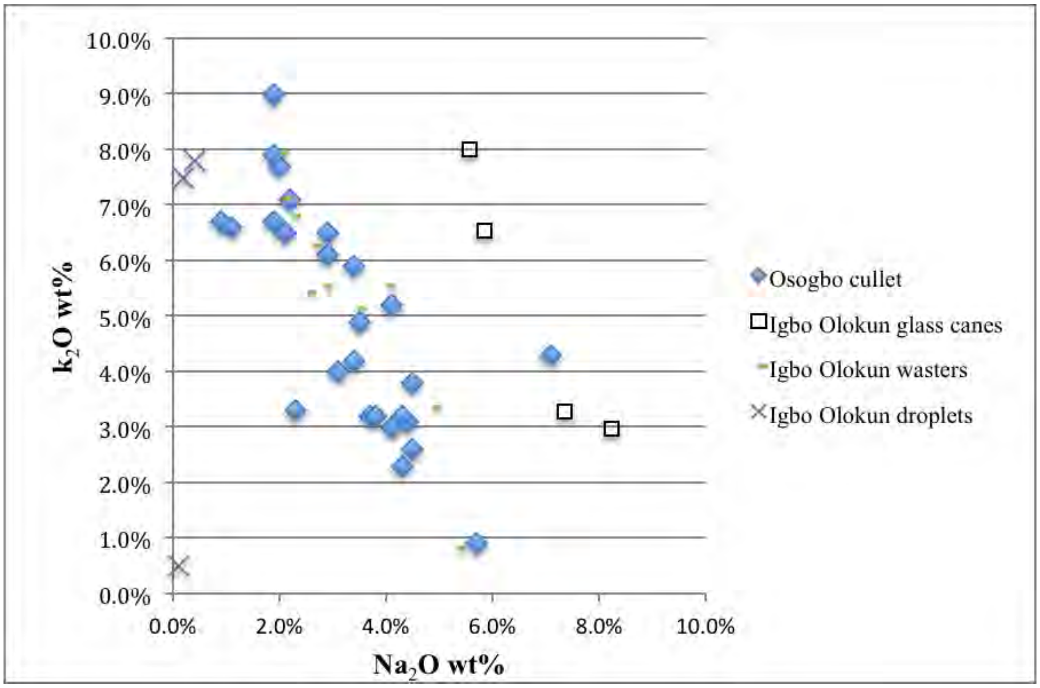


Figure. 8.55: Comparison of the soda and potash content of Igbo Olokun debris with Osogbo cullet.

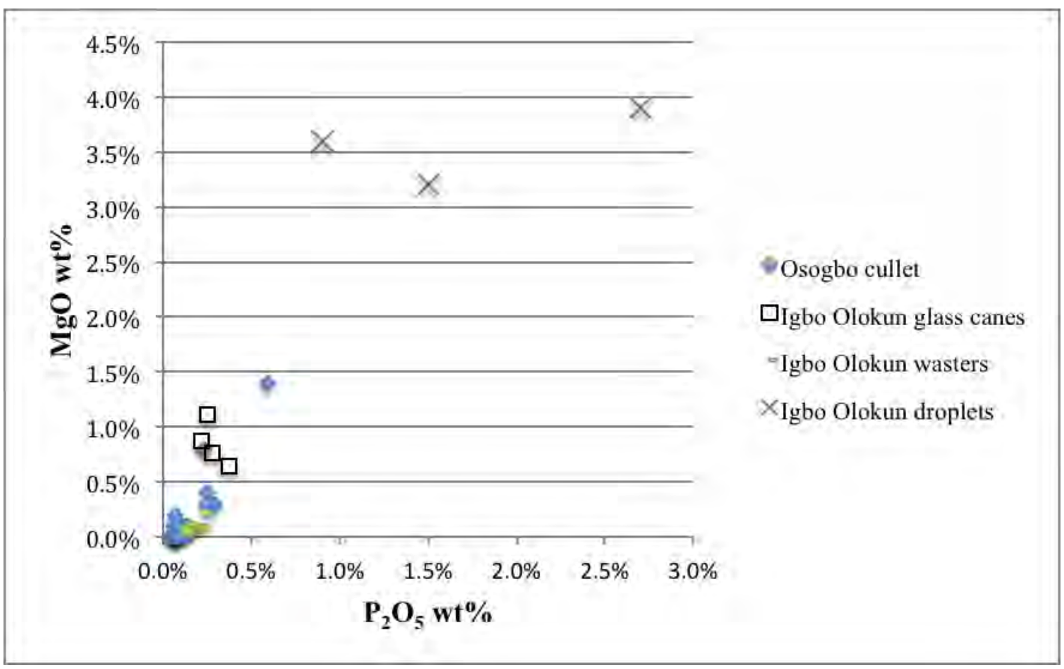


Figure. 8.56: Comparison of the phosphate and magnesia content of Igbo Olokun debris with Osogbo cullet.

Summary

This chapter has presented materials relating to possible glass making and definite glass working at Igbo Olokun, the first time such detailed information has been provided for glass production material from a fully documented excavation in Ile-Ife. Analysis of production-related materials from Igbo Olokun, including crucibles, glass working debris, and vitrified production debris, has allowed assessment of various production stages involved in glass bead making. These processes may have started from glass making from raw material to manipulation of melted glass for bead making. The initial glass making may not necessarily have been carried out at Igbo Olokun. However, the scale of the glass working debris and the unusual compositional group demonstrate the presence of a local glass working industry.

The analysis of crucible fragments is crucial to these arguments. The large numbers of crucible fragments and their distribution at Igbo Olokun and other places within Ile-Ife demonstrates intensive glass working. These crucibles were likely made locally of local raw materials, based on the high content of alumina found in both them and the domestic pottery. The significantly higher alumina (ranging from 25–>35wt%) in the crucible fragments suggests that the clay may have been deliberately sought for making 'technical vessels,' in which increased refractoriness was important. Although the crucible refractoriness and its attributes are the same for working and making glass, the quartz grains floating in some of the inner glass matrix are a possible indication for primary production.

The large assemblage of glass production debris from Igbo Olokun has offered important insights into glass working at the site. The production debris allows us to reconstruct various stages of bead production, from the drawing of glass tubes to reheating of beads for end treatment. The correlation of the chemical composition of the crucible glass with glass canes and other wasters from Igbo Olokun demonstrates that they belong to the same local tradition. This tradition, which may have originated in Ile-Ife, appears to have spread to other Yoruba cities in later centuries, as shown in comparison to material from Osogbo.

The occurrence of vitrified production debris (VPD) from the excavations at Igbo Olokun further indicates that Igbo Olokun was an industrial site where high temperature activities were carried out. The nature of the VPD and comparison with other furnace ruins has revealed episodes of repairs and involvement in high temperature activity suggesting that they may represent furnace remains at Igbo Olokun. The absence of iron slag attached to the VPD and the similarity of the white areas to the outer crucible glass indicates a probable link between the VPD and the firing of the crucibles. It is therefore suggested that the VPD possibly represents fragments of the furnaces used for the glass industry.

Overall, this chapter has presented both the classification and chemical compositional analysis of production related materials from Igbo Olokun. Results of the analysis have both reinforced and extended the argument that there was an important glass-working studio at Igbo Olokun that produced drawn glass beads with a distinctive high alumina composition. Most of these also had high lime levels, but lower lime levels are also present. Comparison of the data from Igbo Olokun with the assemblages from other sites within Ile-Ife reveals that most Ile-Ife glass materials belong to the HLHA group suggesting perhaps a single glass making tradition in or near the site

Chapter 9
CONCLUSION

Introduction

In this dissertation, I have described the methods of data recovery, presented the materials found, and summarized the results of the various analyses carried out on the excavated materials. These results allow us to first present a detailed description of all major find classes, and second to start to develop some qualitative interpretations on the technology of local primary glass working and possibly glass making. It also enhances meaningful interpretation of interaction through regional and long-distance trade networks between early Ile-Ife and other West African communities. In this conclusion, I first consider how this research has made significant advancements on earlier excavations at Ile-Ife. I present the limitations encountered during this study and consider how they may impact our knowledge of glass working and/or glass making at the site. I summarize the evidence supporting the existence of glass working (particularly bead making) at Igbo Olokun, and perhaps glass making in or near the site. This summary is followed by a brief discussion situating my study within the larger context of regional interaction and trade networks among early West African communities. Lastly, I examine how my research has contributed to our understanding of the chronology of glass production in early Ile-Ife.

Significance of the study for Ile-Ife and West African Archaeology

This work marks an important departure from "art-centric" investigations and interpretations that are often synonymous with the archaeology of Ile-Ife. This dissertation provides detailed data on all major find categories and contexts from excavations undertaken at Igbo Olokun and a second site on the outskirt of the city, Igbo-Rudi. This approach is important because it does not favor any material over another but fully reports all finds; this approach of detailing all excavation data is required in order to provide a more complete picture of past activities.

The excavations provided a more nuanced understanding of the Igbo Olokun deposits. Despite the dozens of units dug into by Frobenius, Fagg and Murray, Willett, and Eluyemi, very few details on the depositional contexts and stratigraphy at Igbo Olokun had been published. In our excavations culturally productive layers extend to approximately between 30 and 80 cm below surface overlying sterile red clay. This depositional arrangement is similar to the situation at other Ile-Ife sites, such as Odo Ogbe, Lafogido, Obalara, and Woye Asiri. Frobenius also described the upper 75cm at Igbo Olokun as overlying a red homogenous fire-clay, which must refer to the lateritic clay. Garlake (1974:142) noted that local building practices exposed the lateritic clay for a building surface and also dug into it as source of building material. The uneven surface of the red lateritic clay in the excavated units probably reflects these activities.

In most of the Igbo Olokun units, pits were a common feature. They ranged from relatively shallow pits filled with modern trash to deep, bell-shaped pits with connecting passages earlier described by Willett and Eyo at Igbo Olokun and Odo Ogbe, respectively. Excavation of the deep pit (Pit 2) in unit IO-B/D ended at 2.2 m without reaching sterile. Willett (1960) described Igbo Olokun pits extending to almost four meters, and Frobenius encountered some over five meters deep. The function of this deep pit (Pit 2) could not be determined. No human bone was found to indicate a burial function, as Fagg suggested for the Igbo Olokun pits, and as Eyo confirmed for one of the Odo Ogbe pits. Nor were there notable masses of glass debris, or crucibles that would suggest disposal of industrial refuse. However, two radiocarbon dates from the fill of Pit 2 were widely divergent, one (70 cm depth) dating to the 11th-13th centuries cal AD and the second (143 cm depth) to the 18th-19th century, confirming recent disturbance and mixing of deposits. Did this involve the emptying out and refilling of an ancient pit or the digging of a recent pit that incorporated earlier material in its fill? We cannot determine this at present.

Historical and oral information indicates that pit digging in Ile-Ife was a recurring aspect of site formation. Ritual practices of burying antiquities at shrines, including those at Igbo Olokun, were first described by Frobenius. He also noted that the glass in Olokun Grove was a valued resource that was quarried and "spent" by the Ooni. The Ife glass that the Landers brothers purchased in the market at Old Oyo in the early 19th century likely originated in Igbo Olokun. Willett (1960) reported that the site was still being mined for old glass that could be drilled to make beads. A current resident of Irebami community in Ile-Ife where Igbo Olokun is located recalled facilitating the filling of several holes in the early 1970s that may have resulted from these quarrying activities.

The challenge of Igbo Olokun is the evidence of multiple episodes of disturbance, and the difficulty in detecting these disturbances while excavating. In most cases the disturbances were not detected until we encountered them in the matrix of the sterile red clay or the ironpan. But they are also sometimes spotted in the profile. One consequence of this is our understanding that the material recovered from deposits overlying the sterile clay is likely to represent more than one chronological period. All the excavated levels in Igbo Olokun units TP1, B, D, and E produced pottery, large numbers of glass beads and glass debris, and crucible fragments. There was no spatial focus or concentration that would indicate primary workshop deposits, although the presence of industrial debris is irrefutable. The association of the radiocarbon-dated charcoal with the cultural material in the deposits is thus uncertain. The radiocarbon dates that are most likely to be from primary deposits are both from units outside of Igbo Olokun: OO-A (14th c. cal AD), and IR-TP2 (16th-17th c. cal AD).

The shallow depth of the cultural deposits overlying the lateritic clay at Igbo Olokun and more generally in excavations elsewhere in Ile-Ife excavations is most interesting. In locations such as Woye Isiri, Obalara, and Ita Yemoo, potsherd pavements and ritual deposits dating to the fluorescence period lie close to the surface. At Odo Ogbe, Eyo (1970) reported an early occupation layer with pit and pot burial, subsequent abandonment, and later establishment of a shrine. This suggests that occupation and use of any particular area was relatively brief and followed by abandonment, before later use, if any. Buildup of domestic deposits has rarely been encountered. Alternatively, there may have been episodes of significant erosion or removal of overburden to expose the lateritic clay. Spatial foci including domestic, ritual, and workshop areas apparently shifted through time. Thus the use of space over time was extensive, rather than intensively focused in one place, so sorting out how Ile-Ife developed over time is a complex question that will require enormous effort to excavate throughout the vast area that Ile-Ife encompasses today. The dense occupation of the city today poses a major obstacle to such an ambitious agenda, so archaeological research will most likely focus on small-scale excavations in different part of the town, as circumstances permit.

This state of affairs means that it is not possible to identify specific activity areas at Igbo Olokun. The mixed deposits also make it difficult to determine the association of materials with specific features, such as a furnace and perhaps annealing chamber, with regards to glass working. Although scientific analysis of the vitrified production debris (VPD) revealed chemical signatures suggesting clay materials possibly used in or belonging to furnace construction (Chapter 8), we still lack knowledge of the characteristics, contents/context, and association of the furnace with other materials. Further, the mixed nature of the deposits poses a challenge for radiocarbon dating of charcoal samples as reflected in the later radiocarbon dates from charcoal samples from pit 2 in units IO-B/D, and IO-TP1 (Chapter 4). Considering the small area of the site investigated, further research may one day hopefully overcome these limitations.

The excavation units outside Igbo Olokun – OO-A and IR-TP2 – appear to have more undisturbed deposits and greater stratigraphic integrity among all the excavated units for this research. Materials from these units clearly show that they are related to domestic deposit. Radiocarbon dated from the units also revealed that they were deposited at different time period in early Ile-Ife occupation. While unit OO-A is dated to the “classic” Ife period, IR-TP2 belongs to the 17^{th}–18^{th} century AD. The date from IR-TP2 is particularly significant because it presents us with the opportunity to start investigating post 15^{th} century Ile-Ife material culture and events. The excavations also informed us about the pottery from the early and later Ile-Ife.

A better understanding of Ile-Ife pottery is achieved by providing a multivariate approach. This approach to the pottery from Igbo Olokun and Igbo Rudi significantly improved on Garlake’s (1977) scheme, and provided important insights into early Ile-Ife pottery. The investigations have furnished us with data for comparative studies with known types from Ile-Ife. Classification of the pottery for this study shows that decorations and forms of Igbo Olokun pottery match, to a large extent, with the known 12^{th}- to 15^{th}-century Ile-Ife pottery as identified from the Obalara and Woye Asiri sites by Garlake. However, pottery from Igbo Rudi appears not to fit into the existing scheme and an attempt at intersite comparison reveals differences between the Igbo Olokun and Igbo Rudi assemblages. I have detailed the similarities and differences between the pottery from the two sites in Chapter 5. The difference between these two assemblages may be chronological, marking post-16^{th}-century pottery from earlier traditions. Describing the difference between pre- and post-16^{th} century Ile-Ife pottery had not been approached archaeologically and this study presents the first evidence pointing at the contrast between the ceramic evidence from these periods. Because the excavated sample was extremely small, further work is needed to understand post-16^{th}-century Ile-Ife pottery better. A 17^{th} century radiocarbon date from Igbo Rudi underscores the importance of this site for further investigation.

This study also compared Ile-Ife pottery with other 1^{st} millennium BC sites across Nigeria. This comparative study was once way to investigate the reliability of a series of TL/OSL dates that were much earlier than expected (Chapter 4). The comparison demonstrated that there is little similarity with 1^{st} millennium BC pottery; the multivariate approach does indicate a good fit with pottery traditions from the early through mid-second millennium AD.

Despite over a century since the first report of glass beads from an archaeological deposit in Ile-Ife, this is the first time an assemblage of several thousand is being reported in detail. The detailed description has helped to re-contextualize glass beads in terms of colors and shapes. Beyond the most common monochrome colors, some polychromes were recognized, which reflect the degree of sophisticated skills in the bead production. Similarly, the comprehensive classification has helped to resolve some biases and limitations associated with previous classification schemes for Ile-Ife glass beads. For example, we now know that certain shape categories indicate production processes rather than a desired finished shape. Additionally, the careful documentation of the beads is important as it allows for future research a comprehensive classificatory model for comparison.

As mentioned throughout this dissertation, glass related materials such as beads, crucible fragments, and production debris have been found in 8th through 15th century archaeological contexts in West Africa. However, studies have revealed that most, if not all, represent either direct importation of glass objects from the known centers in the Old World or evidence of secondary glass-working at a household scale. Thus, there is no substantial evidence of early, primary industrial-scale glass-working in sub-Saharan African. In other words, the evidence from Igbo Olokun has no precedence on the subcontinent. Therefore, this study has contributed immensely to our understanding of early technology in Africa, south of the Sahara, offering a comprehensive description of the production debris that indicates early primary glass working. The debris, has allowed for the documentation of different stages and techniques in the production of glass beads in early West Africa.

In conclusion, it is worthy to state that the aforementioned limitations had no negative effect on the interpretation of the technical process involved in glass working. To determine this technical process one only need detailed studies of the chemical composition and a thorough assessment of the production-related materials. This study has provided all of these and built a foundation for future investigations. Despite these challenges, this research provides the first direct evidence of early local primary glass working in West Africa dated to at least the 11th and 15th centuries in Ile-Ife.

Early glass working or glass making?

The analysis and assessment of excavated data from Igbo Olokun have allowed me to investigate issues relating to primary glass production, glass working, and interregional and regional interaction and trade networks. Although the evidence for *primary* glass production at Igbo Olokun is meager, there is abundant evidence supporting glass working at the site, likely dated to the 12th and 15th centuries AD. Here, I summarize the evidence presented in Chapters 7 and 8; I will first discuss the evidence of local primary glass bead making, and then summarize the evidence for possible local primary glass making.

Glass Bead making

The data from Igbo Olokun suggest that all stages of glass bead-making, from the drawing of melted glass to tube cutting, occurred locally at the site. For example one crucible with glass fused on the inside shows that glass of different colors were melted in the vessel; these crucibles were vessels from which melted glass was gathered and drawn to form glass tubes. The presence of collapsed tubes, tube ends, and droplets suggest the drawing of molten glass *in-situ*. Snapped tubular beads, bead discs (miscut), as well as tube ends indicate the process of cutting glass tubes into smaller bead sizes (Francis 1992). Finally, finished beads with well rounded ends, over heated beads, and fused beads are evidence of on-site treatment of glass beads using the reheating technique.

The craftsmen would have employed the treatment techniques whereby a group of snapped beads were gathered in a container with the addition of clay powder to avoid clumping and over-heating (Wood 2011). This treatment technique is different from the 8th–10th century occupation of Gao Saney, where the beads were laid flat when reheated—this resulted in some of the beads having flattened ends with many others melted side-by-side (Cisse 2011). Understanding of this kind of reheating technique may suggest the scale of production at the site. While the clumped beads may indicate industrial scale production, the side-by-side fusing and flattened side suggests household scale production. Research by Francis (1991, 1992) in southern India has demonstrated industrial glass bead making that generated clumped beads similar to those from Igbo Olokun.

Study of the assemblage of glass wasters from Igbo Olokun has also revealed the complexity in the production of certain kinds of beads. The occurrence of solid glass canes without perforation is an indication of the intricacy of making decorated beads. The glass canes mostly occur in dark brown/deep red color. Glass of this color usually appears as an outside coating on beads with a clear core in spiral or striped motif. The bead makers would have used the thin red glass canes as material for making all manner of striped motifs. Allen (1983) has suggested some methods of making striped glass beads. The cross section image of sample IF038 in Figure 7.5 shows that a pressed technique was used in making the stripes on beads at Igbo Olokun. This implies that Davison's (1971: 262) suggestion that "some [Ile-Ife glass beads] bear applied stripes, which are not marvered in, which can be picked off with the finger, and which are sometimes crooked" should be questioned. The pressed technique allows the stripes to cut into the glass core; Davison's suggestion that these were 'applied'suggests that stripes did not have any impact on the glass core. The evidence from Igbo Olokun thus reveals that the glass beads were produced by sophisticated techniques. Although a few striped beads might match Davison's description, the appearance of the stripes as applied may represent semi-finished beads/wasters with the red strip not yet marvered in rather than a reflection of a "crooked or casual" production technique. The process of application of the stripes is consistent with local sophisticated production of complex beads. The examination of a large assemblage has allowed us to identify various processes the materials may have been subjected to, both pre and post-depositional, such as selective corrosion of specific colors. This is a great advantage of working with a large group of materials, which allows for the discovery of variation and provides a clearer perspective on the materials compared to working with selected few finds, as in the case of Davison's research.

The Igbo Olokun data provide strong direct evidence on the glass working, the first evidence of its kind in sub-Saharan Africa. Although evidence of glass-working has been reported from Chibuene – a 6th – 17th-century trade port in southern Mozambique (Wood *et al* 2012), the data lack evidence of the complete production sequence or the local acquisition of raw materials for its production. For example, glass crucibles were absent at Chibuene, and the chemical composition suggests a South Asia origin for the glass (Wood *et al* 2012). In addition, other evidence from pottery indicates that Chibuene was a trade port actively involved in the Indian Ocean trade network between the 8th and 11th centuries (Sinclair *et al* 2012) and thus it is likely that the glass beads and glass shards reached Chibuene through that trade system. In contrast, a full suite of production materials, including crucibles, were found at Igbo Olokun, as well as a unique chemical composition that suggests that raw materials for the glass were likely from Ile-Ife or a nearby source. In addition, the substantial amount of production debris and snapped-end beads suggests local production of glass beads was occurring on site. Although it is clear that glass working was occurring at Igbo Olokun, the question remains as to whether glass was also being made on site.

Primary glass production

I have discussed in Chapter 3 the argument that scholars of ancient glass have put forward that primary glass production centers were few and restricted to certain parts of the Old World, such as Egypt and the Mesopotamian region. Archaeological and documentary evidence support the great antiquity of glass making in these regions. The evidence of primary glass production coupled with the long history of archaeology in Late Bronze Age Egypt and the Middle East has no equal in sub-Saharan Africa. However, as also discussed, the work of Lankton *et al* (2006) and Freestone (2006) have argued for possible primary glass production in or near Ile-Ife. With the archaeological evidence from Igbo Olokun, the question therefore remains whether or not Igbo Olokun was a primary glass-making center. Here I will first summarize materials recovered from the site, and the results of the microscopic analysis of the crucibles and chemical composition of the Igbo Olokun glass. I then assess the evidence to make a case for or against possible primary glass production at Igbo Olokun.

The archaeological investigations at Igbo Olokun recovered substantial materials that confirm glass making and/or working was occurring at the site. The materials include over forty kilograms of crucible fragments with glass of different colors fused on the inside, several thousand fragments of production debris, and many finger-shaped ceramic cylinders that may be connected with the glass workshop (Chapter 8). The excavation also uncovered pit features but these cannot be linked to glass production (Chapter 4). No furnaces were found at the site. However, fragments of what I have termed ‘vitrified production debris’ may be the remains of a furnace although there is need for further analysis of the material in order to understand its true nature and association to production processes at the site.

Chemical compositional analyses of samples from Igbo Olokun by LA-ICP-MS and SEM/EDS have contributed significantly to our understanding of the chemical signature of Ife glass. The results demonstrate the uniqueness of the high alumina glass recipe. Glass with high lime and high alumina (HLHA) and low lime and high alumina (LLHA) are the most common, with HLHA glass the most prevalent across the assemblages at Igbo Olokun. The uniqueness of HLHA glass and the localization of LLHA glass to Igbo Olokun suggest that the recipes for these compositional groups were probably locally made. Glass of other recipes such as soda-lime-silica and the high lime low alumina (HLLA; Davison 1971; Lankton *et al* 2006) has also been recognized from Igbo Olokun, although in many fewer numbers. The occurrence of all these different recipes indicates that both local and imported glasses were been worked at the site, perhaps during different periods. If imported glass were indeed worked or reworked, the question arises at what time period craftspeople at Ife start to import glass and for what reason. These questions remain unanswered and will hopefully be pursued in future investigations.

The optical microscopic examination of cross sections of crucible fragments followed by SEM/EDS analyses, compositional analysis of the inner glass, fabric, and the outer glaze were extremely useful in understanding the technical and functional aspects of the crucibles. A number of results from these analysis suggest that glass was being worked, including: the quartz grains preserved in the matrix of the inner glass of the crucible; the presence of swirls in the inner glass; and the correlation of the inner crucible glass, the outer glaze, the wasters, and the glass beads.

The compositional studies have also demonstrated the unusual nature of the recipe for the HLHA. Since this recipe is not known from other glass-making centers, the primary production of glass in or near Ile-Ife is a very likely possibility.

While the evidence from Igbo Olokun directly supports an argument for glass working, the evidence of primary glass making is only obliquely indicated in the data. As it has been demonstrated elsewhere, quartz grains and swirls in the crucible inner glass may represent evidence of local glass making. Yet this data requires additional supporting evidence such as *in-situ* furnace remains or other production materials beyond that of crucibles. The lack of such evidence does not rule out the possibility that Igbo Olokun was a workshop where both primary glass making and glass working were carried out. The excavations reported here represent only a small fraction of a very large site and additional evidence may exist at Igbo Olokun.

It is also possible that glass was carried out at another site close to Igbo Olokun. The only known site in Ile-Ife that has yielded materials similar to those from Igbo Olokun is Ayelabowo, excavated by Adeduntan (1985). Although Adeduntan (1985) argues that the site was a glass-bead-making center dated to the early 1st millennium AD, there is need for reexamination of the site in order to establish if there is any relationship with Igbo Olokun in terms of the technique of production and its products. If glass was being produced elsewhere, Igbo Olokun would have been a glass studio where locally-made glass was brought to for bead making. In sum, it is unclear whether or not Igbo Olokun was a primary glass making center, but it is clear that the site was a glass working workshop specialized in bead making. The beads were mass-produced on an industrial scale, and widely distributed within and beyond the Yoruba region.

Regional and Interregional Interaction

Studies of Ile-Ife pottery have provided an avenue for considering regional interaction (Chapter 5). For example, Ife pottery has been found in some central Yoruba communities, such as Ilare district, dated to the 13th to16th centuries AD. Ife pottery decorative styles and vessel forms have also been found in Edo-speaking regions, suggesting interactions with this area. Pottery with Ile-Ife motifs have also occurred in northern Yoruba frontier communities of the 13th century AD (Usman 2012). By the 16th to 18th centuries, however, Ile-Ife ceramics were displaced by pottery of the Old-Oyo tradition.

In addition to the evidence of interaction through pottery studies, the results of the analysis of the glass assemblage have also helped to situate Igbo Olokun among other important early West African communities such as Gao in Mali and Igbo Ukwu in southern Nigeria, in order to examine both inter-regional and regional interaction and trade networks. For example, there is evidence that the HLHA and LLHA glass beads were circulated within West Africa. HLHA glass beads are found in Gao and Essouk in Mali, and Kissi in Burkina Faso. HLHA glass beads were also present at Igbo-Ukwu, southeast of Ife. The presence of HLHA beads at these West African communities suggests that Ile-Ife was actively interacting with these societies possibly sometime between late first and early second millennium AD, through trade or exchange. The low quantity of Ile-Ife-type glass at these sites raises the question of whether such beads were systematically traded or moved around by traders or pilgrims.

But Ile-Ife was not only producing materials to be traded out. The presence of soda-lime-silica and HLLA glass at Ile-Ife indicates that individuals at Ile-Ife were importing glass as well. Such evidence of a trade network supports Horton's (1979, 1992) claim that a trading economy was an important factor in the prosperity of early Ile-Ife. Expanding on Shaw's (1973) view that on the importance of Ile-Ife's location, Horton (1979: 100) suggests that "for long-distance traders coming down from the north … a route due south from the [Niger] Bend, terminating in or near Ife, would represented the shortest overland path to accomplish their purpose" that is, trade. Therefore, trade in glass beads would have contributed significantly to the economy of Ile-Ife on one hand, and must have been a major form of regional and trans-regional interaction on the other hand.

Nevertheless, understanding the period Ile-Ife began to import raw glass or glass beads of the Islamic world is still largely unknown. Was the experience with Islamic glass or a shortage of supplies of Islamic glass an impetus for developing local recipes? Did the importation of Islamic glass pre- or post-date the local production of glass? The answers to these questions are not answerable with the data at hand.

On the question of chronology

There have long been questions about the chronology of glass working at Ile-Ife; the process has most commonly been dated through its association with other material culture classes, such as ceramics. This dissertation has produced the first direct dating of a crucible from Igbo Olokun. Several charcoal samples associated with other production materials were also radiocarbon dated. To consider the chronology of glass working at Igbo Olokun and Ile-Ife at large, we must first examine how our knowledge of glass making/ working fits within the established chronology for other Ile-Ife materials, such as pottery. The examination of pottery from Ile-Ife has helped to suggest the period between the 12^{th} and 15^{th} century as the peak of Ile-Ife cultural manifestation. The existing pottery scheme served as mirror for understanding of the pottery materials from our excavations at Igbo Olokun and Igbo Rudi. The correlation of the pottery and radiocarbon dates from our excavations with the existing data suggest the chronology of Igbo Olokun to be in-line with the known period (i.e. 12^{th}–15^{th} century). However, the two recent radiocarbon dates from TP1 and IO-D raised the question of whether, in these mixed deposits, the crucibles could be from a more recent period of glass-working.

In view of this later date, TL/OSL analyses of several crucible samples were carried out to see whether the crucibles were more consistent with the classic Ife C14 dates or the later dates Unexpectedly, three of the crucible samples gave dates ranging between 500 BC and 680 BC. The other two fall even earlier, between 1790 BC and 1980 BC. This inconsistency of the result of the TL/OSL dates with the established chronology for Ile-Ife occupation presents more complicated situation. The fact that two crucible fragments from the same context – Level 6 in unit IO-B/D – produced dates as much as a thousand years apart suggests that a critical approach to thinking about all these dates is necessary.. Here I examine two possible case scenarios. First is the possibility that the TL/OSL dates point to crucible fabrication, use, and glass working prior to the 12^{th}-15^{th} century AD fluorescence of Ile-Ife, second is the possibility that the TL/OSL dates are all anomalous, and that the pottery, the charcoal mixed with the production debris, and the beads correctly date the glass technology at Igbo Olokun to the 12^{th}-15^{th} centuries.

In the first scenario, it could be that there was a previously unknown earlier occupation that produced glass in the second and first millennium BC. However, the technology of drawing glass canes for bead does not appear in the archaeological record of the Old World until about the 2^{nd} century BC, first in South Asia, which later spread and significantly developed in the Roman period (Francis 1990). This scenario would require some corpus evidence of local manipulation of lesser vitreous materials leading to indigenous development of glass technology. This evidence is presently lacking. Nor is there any evidence for distribution of the Ile-Ife HLHA type of glass at any second to mid-first millennium BC sites in West Africa, including the numerous excavated Nok sites, in which stone beads were important. The three mid-first millennium BC TL/OSL dates correspond with the production of glass in the Mediterranean Iron Age. The difference in the composition of the Ile-Ife glass and Iron Age glass indicates that the technology was not transferred from these. There is no evidence for first millennium BC occupation in Ile Ife, excepting the single 350±115 BC C14 date from a mixed context of potsherds and microliths excavated in the 1960's. TL dates on the potsherds ranged from the tenth to sixteenth century AD (Willett 1971: 367). Additional systematic survey to identify sites of older deposits in and around Ile-Ife, as well as more excavations and dating of more crucibles may help to investigate these hypotheses.

To consider the latter scenario of anomalous dates, the reliability of the TL/OSL dating results must first be examined. As it stands, there is no evidence of gross anomalies associated with the TL/OSL laboratory analysis. All the results seem robust, with one possible exception, UW3023 with an OSL age scattering of 14th century AD. According to the specialist this date was "based on only two aliquots … The TL and IRSL ages were older for this sample, and no other data from any other sample supported this younger age" (Feathers 2015 Appendix A, 4:13). One possible source of the anomalous dates is the dose rate on the soil samples submitted. Luminescence ages are calculated as a ratio of the equivalent dose of accumulated radiation (the amount required to produce the luminescence stimulated from the archaeological sample in the laboratory) to the dose rate (the annual radiation dose rate to which the sample has been exposed since it was formed or last fired, in the case of crucibles). If the soil sample dose rate does not accurately reflect the radiation environment of the archaeological sample, the luminescence date can be significantly affected. The prevalence of disturbed and mixed deposits at Igbo Olokun raises the question of whether the crucibles were recovered from the deposits in which they originally lay and whether the soil samples submitted were associated with the crucibles. Anomalously early dates will result if an unassociated soil sample has a much lower level of gamma radiation than the true radiation environment in which the archaeological sample was originally deposited and remained for some amount of time. Because the crucibles from Igbo Olokun do not appear to have been *in situ* in primary deposits, this scenario could be applicable.

The two crucible samples (UW3022 and 3023) reported from the same level in the combined unit IO-B/ D illustrate the implications. A separate soil sample was submitted for each crucible. The luminescence dates for the two crucibles differ by approximately a thousand years (Appendix A.13). The gamma radiation component of the dose rate for the soil sample submitted for UW3022 was double that for the soil sample from the same level submitted for UW 3023 (0.92±0.08 and 0.44±0.04; Appendix A.13). Since soil samples were uniformly collected from the center of each excavated level, there is no way to know whether the samples were in proximity to the crucible samples or reliably associated with them. If we substitute the higher gamma dose rate from the UW3022 soil sample into the dose rate calculation for UW3023, the resulting date is a half millennium more recent. Willett (2004:35) reported that the radiation from soil samples associated with archaeological materials from Ife varied by a factor of 4. This is perhaps the most likely factor contributing to the early dates on the crucibles. Much more work needs to be done to locate primary workshop deposits where we may be sure that crucibles are in their original context.

The question of how old is the glass making/working in or near Ile-Ife is thus still unanswered. I will hypothesize that glass working was most likely to predate the so-called classic Ife. There is no doubt about the intensive use of glass beads in the 12th – 15th centuries AD. This is crystal clear from the adornment of several Ile-Ife bronze figures and terracotta with beads, which may indicate that glass beads were already in significant use by the 12th century AD. The evidence of use of glass beads in the 12th century does not, I will argue, suggest the beginning of glass working. To attempt to date the production of the HLHA glass we need to consider the occurrence of this glass type elsewhere, and its associated context. At Ile-Ife Orun Oba Ado and Ita Yemoo are the two sites with known chemically analyzed HLHA glass. Davison analyzed beads of HLHA composition from pit III, V, XI from Orun Oba Ado. Charcoal samples from these pits yielded radiocarbon dates of between the 8th–11th. However, the context of the pit deposit is problematic to be associated with the HLHA glass. Garlake (1974:91) has emphasized the uncertainties involved in connecting the pit fills at Orun Oba Ado with dated charcoal from the pits .In discussing the HLHA glass beads from Orun Oba Ado, Lankton *et al* (2006:126) conclude that "the dated charcoal was very unlikely to post-date the twelfth century, and that a ninth to tenth century date was more likely". Does this time period incontrovertibly date the HLHA from Orun Oba Ado? A consideration of Ita Yemoo may offer a better clue.

At Ita Yemoo HLHA glass was excavated from shrine 2, which is dated to 11th–13th century AD (Willet 2004; Davison 1972). Davison (1972: 267) explains that the crucible fragments from Ita Yemoo were *in-situ*, meaning that, at least, a connection can be established between the HLHA glass and the 11th century date. Based on the situation at both Orun Oba Ado and Ita Yemoo, Lankton *et al* (2006: 126) concludes that "If [the dated] charcoals [from Orun Oba Ado] are representative of the entire fill materials, something that can now neither be proved or disproved, the dates for the HLHA glass would be similar to those from Ita Yemoo, and possibly earlier." I think Lankton *et al's* (2006) conclusion is reasonable, but where else can we look for dating the HLHA glass?

Unlike Orun Oba Ado and Ita Yemoo, Igbo Ukwu has yielded substantial quantity of HLHA. Lankton *et al's* (2006: 127) careful analysis of the dates from Igbo Ukwu demonstrates " a wide possible range of between the 8th and 11 centuries AD" for Igbo Rich where HLHA glass beads were associated. No HLHA glass was found at the other Igbo Ukwu sites with dates. Based on the evidence thus far from these three site of HLHA Lankton *et al* concludes on the chronology of the HLHA glass at Ile-Ife:

> "at any rate, the eighth to twelfth century date for HLHA glass at Igbo-Ukwu supports the similar dates for HLHA glass from Ita Yemoo and Orun Oba Ado in Ile-Ife, and has the benefit of a more explicitly stated association of the dated material with the HLHA beads" (Lankton *et al* 2006: 127).

The evidence and arguments by Lankton *et al* (2006), to a large extent, support the argument for the production of the HLHA glass, assumable, prior to the classic era in early Ile-Ife. However, to properly establish a sound chronology for early glass working in Ile-Ife excavation of deposit with better stratigraphic integrity is needed. May be some day we will be fortunate to stumble on such site in Ile-Ife.

While the plan to excavate more areas in Ile-Ife is underway and for the future, what can be glean from the occurrence of crucibles all over Ile-Ife in terms of the spread and knowledge of the industry. As discussed in chapter 8, crucible vessels both complete and fragments have been found across Ile-Ife. It is worth noting that most, if not all, of the glass crucible found outside Igbo Olokun were in ritual context with associated sculpture, stones, and offering pots. In some cases these ritual materials lay upon potsherd pavement representing sacrifice objects (Garlake 1977; Willet 2004). The sites of such findings had very little or completely lacked other evidence of glass working – particularly production debris. Although Willett (2004: Chapter II.29) reports a complete crucible holding strings of beads and another offering pot with 1850 beads of stone and glass from shrine I at Ita Yemoo, he concludes that they may have been part of the royal or priestly regalia. There are several other cases of individual isolated crucible finds around Ile-Ife that completely lack context. The low frequency of glass beads and crucibles from the 12^{th}-14^{th} century sites of Woye Asiri, Obalara, and Odo-Ogbe may indicate a shift in the use of the crucible from an industrial apparatus to a ritual and personal object. Hence, by the 12^{th} century in addition to the use of crucible in industrial activities, it also became a common ritual objects and receptacle for valuables – e.g. beads. Other isolated crucibles may have been intentionally buried as personal luxurious belongings in the same period.

The evidence of glass bead making at Ayelabowo is an exception to the ritualistic scenario described above. However, Adeduntan's (1985) report of the excavation at Ayelabowo site lacks detailed description of the finds to firmly conclude that Ayelabowo was really a site of glass working or another case of reused context. Alternatively, it is not impossible that there were more than one glass working industry in early Ife. If we consider the possible high demand of Ile-Ife glass regionally and trans-regionally then the argument for multiple glass working industries in early Ife would be reasonable. Eluyemi's (1986, 1987) report of multiple glass furnaces somewhere within the vicinity of Igbo Olokun is an interesting case. The report is explicit enough on the characteristic of the glass beads and debris found from the excavations, which strongly support an industrial activity (Eluyemi 1987: 203-214). However, the report omitted some details that would have helped to relocate and resituate the site within the larger Igbo Olokun glass industry. Only through a rigorous archaeological survey with follow-up multiple excavations that are well distributed across the city would we be able to investigate whether or not there were multiple glass working centers in early Ile-Ife.

In sum, this dissertation has presented a comprehensive report of archaeological investigations carried out at Igbo Olokun, Ile-Ife. As opposed to the tradition of selective reporting of archaeological research in Ile-Ife, this project has demonstrated the significance of all-inclusive reporting that describes all excavated materials in great details. Although we cannot claim that this dissertation has solved the problems associated with Ile-Ife pottery studies, it has at least established a pathway that future research could build upon. Our knowledge of the composition of Ile-Ife glass has been significantly expanded and has strongly demonstrated the significance of the unusual HLHA glass in early Ile-Ife. The recipe and raw material for the HLHA would have been locally sourced and the glass locally made in or near Ile-Ife, as earlier suggested by Omotosho Eluyemi and James Lankton *et al*., Ian Freestone, and Akin Ige. Glass of another recipe (LLHA), but similarly to the HLHA, would have also been worked in the workshop at Igbo Olokun. Comparison of the data from Igbo Olokun with other sites of glass materials in Ile-Ife shows the prevalence of the HLHA glass in Igbo Olokun.

This dissertation work has also provided us with evidence beyond reasonable doubt that Igbo Olokun was working glass and making beads from local glass. The data from Igbo Olokun reveal that tube drawing and cutting and beads end treatment were carried out at the site. Although I have discussed an earlier chronology for glass working at Ile-Ife, no concrete position can be made yet on the exact chronology for this impressive craftsmanship.

Despite the abundance evidence of local glass working at Ile-Ife, we still do not have enough knowledge of the origin of the Ife glass technology. For example whether the technology of Ife glass was independently invented or transferred is not clear yet. If independent, what was the impetus? Was there any initial knowledge of or contact with other vitreous materials that would have stimulated the invention? If transferred, from where did the technology come from? What was the medium through which it reached Ile-Ife? The excavations carried out thus far represent a very small part of what would have constituted the production remains from a glass workshop. Hopefully, more evidence in the near future would help to answer some of these questions, particularly those relating to the chronology and the origin or stimuli for the technology. However, this dissertation has contributed significantly to our understanding of Ile-Ife archaeology as well as the historiography of early technology in Yorubaland. Also it has advanced our knowledge of early glass working in Sub-Saharan African and the rest of the Old World.

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Appendix A

Appendix A.1

Report of palynological study of samples from Igbo Olokun, Unit 1O-C, Ile Ife, Osun State, Nigeria

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The aims of this study are firstly to identify the pollen and spores present in the samples obtained from the excavated unit IO-C in Igbo Olokun. Secondly, using the information so obtained, to reconstruct the vegetation history of Igbo Olokun and thirdly to decipher human-environment relationships at the study site.

Present-day vegetation of Igbo Olokun

Igbo Olokun in Yoruba means Olokun's grove. Olokun is one of the deities of Ife, a water goddess in fact, and it was from this site that the Olokun head was excavated by Leo Frobenius in 1910 (Platte, 2010). At the time of Frobenius's excavation, the site would have been a forest which explains why it was termed an *Igbo* (grove). Today, the vegetation is quite different. Although the area has been fenced around by the National Commission for Museum and Monuments (NCMM) with the intention of preserving it, there has been some human encroachment there evidence of which is the abundant stands of *Musa sapientum* and *M. paradisiaca*. Other plants in the site include *Newbouldia laevis, Samania saman, Ficus exasperata, Colocasia esculenta, Psidium guajava, Vernonia amygdalina, Tectonia grandis, Datura* sp., *Sida cauta, Chromolaena odorata, Ageratum conyzoides, Acalypha* sp., *Citrus rotundifolia, Commelina* sp., Combretaceae and Curcubitaceae.

Fig 1: Vegetation of Igbo Olokun, Ile-Ife, Osun State, Nigeria

Soil samples were obtained from the southern wall of the 130m deep excavated trench named Igbo Olokun Unit 1, 10 C at 10cm intervals; a total of thirteen samples were thus obtained and subjected to pollen analysis using the methods of Faegri and Iversen (1989). 10ml of the final residue was pipetted onto a slide and studied under an Olympus microscope. All these were carried out at the Palynology Laboratory, Department of Archaeology and Anthropology, University of Ibadan, Ibadan, Nigeria. A total of 52 palynomorph types were recovered from the samples; 44 were identified while eight could not be identified. Of the former number, 13, 18, 13 were identified to species, genus and family levels respectively. The identified palynomorphs were grouped into four phyto-ecological groups. This grouping was based on the natural habitats of their presumed parent plants (Keay 1959; Hutchinson and Dalziel, 1958–1972). These phyto-ecological groupings reflect some major vegetation zones in Nigeria; they are as follows:

Lowland rainforest
Blighia sapida
Bosquiea angolensis
Celtis cf. *brownii*
Morus mesozygia
Newbouldia laevis
Triplochiton scleroxylon

Secondary forest
Alchornea sp.
Elaeis guineensis
Pavetta sp.

Guinea savanna
Bridelia ferruginea
Lophira cf. *lanceolata*
Parinari sp.
Phyllanthus discoideus
Poaceae
Protea sp.
Pterocarpus sp.

Montane forest
Podocarpus milanjianus

Others which could not be so classified were categorised separately as presented below:

Herbs and Weeds
Adenia cissampeloides
Alternanthera sp.
Amaranthus cf. *caudatus*
Asteraceae
Celosia cf. *argentea*
Cyathula sp.
Phyllanthus pentandrus
Talinum triangulare

Ferns
Monolete spores
Polypodium vulgare
Pteris sp. 1
Pteris sp. 2
Pteris sp. 3
Stenochlaena palustris

Fungi
Baculate spore
Fungal spore

Miscellaneous
Anacardiaceae
Arecaeae
Combretaceae/Melastomataceae
Euphorbiaceae
Myrtaceae
Papilionaceae
Sapotaceae
Solanaceae
Solanceae
Zanthoxyllum sp.
3-porate grain
3-colpate grain

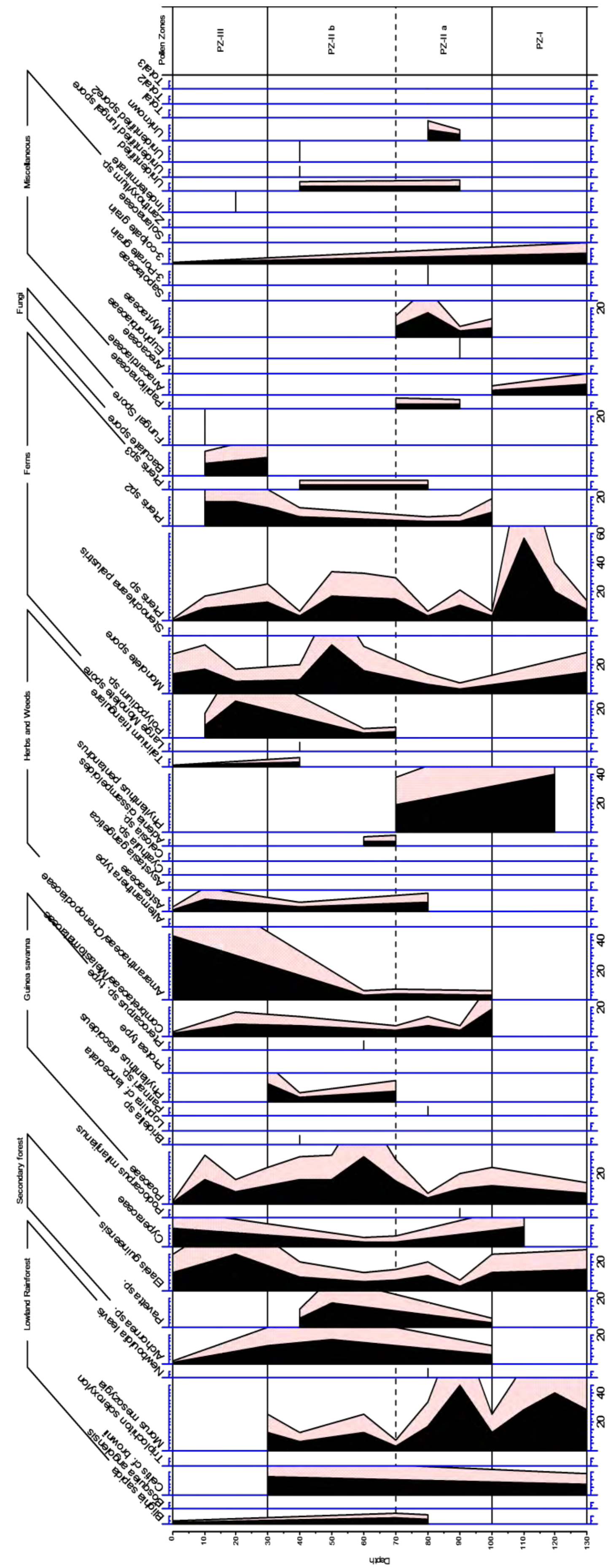

Fig 2: Pollen diagram of Igbo Olokun, Ile-Ife, Osun State, Nigeria

The pollen diagram above was plotted using TILIA computer software (Grimm, 2011). It is divided into three pollen zones, PZ I (Pollen Zone I), PZ II and PZ III; PZ II is further divided into two subzones, PZ II a and PZ II b. These divisions are based on the marked changes in pollen assemblages. This means that a zone is characterised by significant change in pollen types and by implication vegetation and/or environment. Below is a description of each pollen zone.

Interpretation of Pollen Zones

PZ I (130-100cm)

In this zone, *Morus mesozygia* (12.5-40%), *Celtis* sp. (7.1%) and *Pteris* sp. (7.1-57.1%) are the most abundant species; *Elaeis guineensis* (12.5-14.3%), Poaceae (7.1-12.5%) and monolete spores (14.3%) were also well represented. *Phyllanthus pentandrus* (40%) occurred half way in the trench; in the latter part of the zone *Pteris* sp.1 (3.1%) decreased significantly. Similarly, *Morus mesozygia*, *Pteris* sp.2 and monolete spores decreased while other palynomorphs remained with the appearance of *Alchornea* sp. (6.3%); *Amaranthus* cf. *caudatus* (3.1%) and *Alternanthera* (3.1%) were very few.

PZ II a (100-70cm)

At the beginning of the zone, *Morus mesozygia* increased gradually and peaked at 90cm (44.8%); Myrtaceae and *Pavetta* also increased while *Celtis* sp. remained unchanged. In contrast, *Elaeis guineensis, Alchornea* sp., *Phyllanthus pentandrus*, Cyperaceae, Poaceae and Combretaceae/Melastomataceae decreased. There were fluctuations in monolete spores and *Pteris* sp., *Pteris* sp2, and fungi spores; the pollen of *Podocarpus milanjianus* (3.4%), and *Newbouldia laevis* (3.3%) and *Parinari* sp. (3.3%) appeared at 90cm and 80cm respectively. The occurrence of the latter two coincided with gradual increase and decrease in Poaceae and Moraceae respectively. Towards the end of the zone, *Morus mesozygia* decreased significantly (3.8%); Myrtaceae and Cyperaceae experienced slight decrease and *Blighia sapida* appeared. *Elaeis guineensis*, *Alchornea* sp., Combretaceae/Melastomataceae, Poaceae, monolete and trilete spores (*Pteris* sp.) all increased. Herbs and weeds represented by *Amaranthus* cf. *caudatus* (3.1-3.6%), *Phyllanthus pentandrus* (18.5%) and Asteraceae (6.7%) were present.

PZ II b (70-30cm)

Morus mesozygia (12.5-3.6%) and *Celtis* (12.5%) decreased and both eventually disappeared at the end of the zone; they were never recovered again from the trench. Secondary forest taxa (*Elaeis guineensis* [6.5-9.7%], *Alchornea* [12.5-16.7%] and *Pavetta* sp. [6.5-16.7%]) were well represented; Poaceae was generally fairly abundant; it peaked at 60cm (32.2%) but decreased (12.5%) at the end of the zone. Savanna taxa (3.2-12.5%) such as *Bridelia ferruginea, Phyllanthus discoideus* and *Pterocarpus* became well represented while pollen of herbs and weeds were present among which *Amaranthus* cf. *caudatus* (3.2-3.7%) and *Adenia cissampeloides* (3.2-3.7%) were the most abundant.

PZ III (30-0cm)

Herbs and weeds dominated this zone among which Asteraceae (1.6-8.3%) and *Amaranthus* cf. *staudii* (43.2%) were the most abundant; *Talinum triangulare* (0.5%) was also present. Forest species such as *Morus mesozygia* and *Celtis* disappeared but *Blighia sapida* (1.1%) was present albeit only at 0cm; *Alchornea* (12.5-1.1%) and Combretaceae/Melastomataceae (8.3-1.5%) decreased significantly but *Elaeis guineensis*

(12.6-24.9%) was well represented. Cypearceae (12.6%) increased indicating some swamp environments. Poaceae fluctuated and eventually decreased at the end of the zone (8.3-1.1%); similarly savanna pollen became drastically reduced to 0.5%. In contrast, ferns represented by monolete (14.1-33.2%) and trilete spores (0.5-24.9%), and fungi (12.5-24.9%) were abundant.

DISCUSSION

PZ I (130-100cm)

The abundance of *Morus mesozygia*, *Celtis* and *Pteris* sp. showed that the environment was a forest and that climate was relatively humid. The latter suggestion is because *Pteris* sp. occurs in wet environments. Though *Morus mesozygia* and *Celtis* are forest species, they are natural to dry/open forest suggesting that the forest at this time was a dry and open one i.e. a secondary forest. The fair abundance of *Elaeis guineensis* and Poaceae supports the inference that the vegetation was an open or secondary forest. The former grows abundantly in artificially altered forest while the latter, though ubiquitous, is hardly found in forest with closed canopy and is indicative of open environment; its occurrence is consistent with a secondary forest. However, the presence of ferns [monolete spores and *Pteris* sp. (trilete spore)], suggest a somewhat humid environment. Thus, the vegetation in the early part of the zone was a humid secondary forest. At the end of the zone, the decrease in *Morus mesozygia*, *Pteris* and monolete spores, and the appearance of *Alternanthera*, Combretaceae/Melastomataceae, *Amaranthus* cf. *caudatus* and *Alchornea* suggest some vegetation changes under the influence of humans. The pollen evidence indicated that the environment became more open and dry. In addition, the occurrence of the pollen of the weedy plant—*Phyllanthus pentandrus*—as well as those of *Elaeis guineensis*, *Alchornea*, *Alternanthera* type and *Amaranthus* cf. *caudatus* pollen suggest some human impact on the vegetation. The abundant number of glass beads recovered from this excavated unit suggests that the site was used for bead production in the past. But it is not clear whether certain 'special' plants were used for this purpose. What is certain is that forest trees would have been felled for use as fuel for the bead making process. One of the pollen identified as *Amaranthus* resembles that of *A. caudatus* i.e. the cultivated *Amaranthus* species used as vegetable (*Tete*) by the Yoruba people. If so it may have been deliberately cultivated albeit on a small scale. This is evidence of human impact on the site. However, the inferred human impact is minimal considering the low occurrence of the human indicator pollen.

PZ II a (100-70cm)

The vegetation in the beginning of the zone was not significantly different from that of the preceding zone. Forest increased with concomitant decrease in human impact indicator pollen such as *Elaeis guineensis*, herbs and weeds. Perhaps, human population during this time was small and their activities within or near the grove was minimal which probably allowed for expansion of the forest. The subsequent occurrence of *Podocarpus milanjianus* and *Parinari* suggest slight changes in the environment. The former is a montane taxon while the latter is a guinea savanna species. Because Ile-Ife is located deep in the forest, the occurrence of a montane taxon signals some wind activity and distant transport of its pollen from highlands to the north such as those in Ekiti and Ondo States (Orijemie, 2013). This inferred wind activity was also responsible for the transportation of *Parinari* from the north (savanna) into the area. It is important to note that these events coincided with increase in Poaceae and decrease in forest represented by *Morus mesozygia*. All these indicate the occurrence of some dry conditions in Ife which would have been more severe at least to the north of the Ife area. In other words, natural dry conditions caused a reduction in forest species whilst savanna taxa and those which could withstand the slight change remained. This period seems to coincide with the Little Ice Age which occurred between the 16th and 19th centuries effect of which was global. It appears the people came to realise the potentials of the area for agriculture. They thus took advantage of the now more open forest and cleared the remaining area for farming evidence of which are (1) further reduction in forest taxa which might be related to bead making activities particularly the use of forest wood as fuel, (2) increase in economic trees (*Blighia sapida* and *Elaeis guineensis*) which the people might have deliberately protected, and (3) the gradual increase of pollen indicative of cultivation and disturbances (*Alchornea* sp., *Amaranthus* cf. *caudatus*, *Phyllanthus pentandrus*, and Asteraceae). The subsequent occurrence of Cyperaceae and increase noted in ferns represented by monolete and trilete spores, particularly the latter, suggests that the environment, though open, became relatively humid.

PZ II b (70-30cm)

The reduction noted in forest taxa and concomitant increase in secondary forest particularly *Elaeis guineensis* and *Alchornea* indicate artificial opening of the forest for the purpose of cultivation (Sowunmi, 1981). The slight increases in *Amaranthus* cf. *caudatus* and *Adenia cissampeloides* supports the above inference. *Amaranthus* cf. *caudatus* an edible vegetable, and can naturally be found in disturbed areas; *Adenia cissampeloides* is a weed often seen in disturbed lands. The appearance of savanna taxa (*Bridelia ferruginea, Phyllanthus discoideus* and *Pterocarpus*) is significant. These species can be found in the Guinea savanna as well as Derived savanna. The latter is actually the northernmost extent of the forest; it is in fact a forest degraded by several years of human activities (Keay, 1959). In addition, the initial increase in Poaceae is in line with the suggested inference of artificial opening of the forest for the purpose of cultivation. The representation of pollen of derived savanna taxa and high value of Poaceae in a forest region suggests further degradation of the forest. It is also possible that seedlings of these savanna plants were accidentally transferred from the north via trade and nomadic farming particularly as part of the gains of bead trade. Subsequently, Poaceae and savanna taxa decreased but ferns were present showing that climate was still humid. The slight increase in *Morus mesozygia* after a decrease indicated that the forest degradation in the grove was done on a small and irregular scale. This would have been possible with the decline in reverence for the Olokun deity.

PZ II b (30-0cm)

The absence of savanna and decrease in Poaceae shows that the environment was humid. This is corroborated by the abundance of ferns (monolete and trilete spores) and fungi. These plants thrive well under humid conditions; such conditions are favourable for forest growth. In contrast, the pollen evidence reveals a near disappearance of forest taxa. That the near disappearance of the forest coincided with high values of the pollen of economic plants, and unprecedented values in weeds are significant, and signals marked human activities. Although this might not be the only factor, the marked reduction of the forest may have partly contributed to the eventual death of bead making and its technology in Ife. This is because wood fuel was crucial for bead production, and without it the trade could not simply survive. The abundance of plants of economic importance such as *Elaeis guineensis* and *Blighia sapida* is consistent with a slash and burn agricultural practice where selected trees are deliberately protected hence the abundance of the pollen of these plants in this zone. In addition the occurrence of *Talinum triangulare* indicates intensified agricultural practices. The near absence of forest indicates that the Olokun deity perhaps was no more worshipped or at least lost its relevance, and its grove desecrated by felling of trees and cultivation of economic plants within the grove for food. The zone appears to cover the latter part of the last century because of the following reasons. Firstly, when Leo Frobenius and his team visited Ife in December, 1910, there was still a guardian of the Olokun grove with whom he negotiated the Olokun head (Platte, 2010). This suggests that part of the Olokun forest existed one hundred years ago which necessitated the presence of a priest/guard. But at the time, the sediments of zone III were deposited, the forest was gone indicating that these sediments (30-0cm) were deposited after Frobenius' visit. Secondly, it was under this period (1950-date) that there was unprecedented destruction of forest worldwide (UN Report). A similar situation (forest reduction) was also noted for the topmost levels of the excavated trench in Ajaba, located to the north of Ile-Ife (Orijemie, *et al*., 2010). It then appears that human impact on the forest zone in south western Nigeria became more severe in the historic phase of the late Holocene (Orijemie, 2013)

Conclusion

The pollen analysis of 13 samples from Igbo Olokun Unit 10 C, Ife showed that at the beginning of Ife's founding, the area around the Olokun grove was dominated by forest species among which *Morus mesozygia* and *Celtis* cf. *brownii* were the most abundant; climate was relatively humid. This rich forest supported bead production by being a source of wood fuel necessary for the production of glass beads. The forest here was, however, not a wet type having survived periods of both natural and anthropogenic influence. At some point, the occurrence of montane and guinea savanna taxa indicated dry conditions which could be the result of the little ice age. Subsequently, the forest began to decrease until it disappeared at the top of the trench; and this was partly responsible for the demise of glass bead production. The forest was replaced by economic plants (*Blighia sapida* and *Elaeis guineensis*) and herbs (*Amaranthus* cf. *caudatus* and *Talinum triangulare*) which are indicative of human activities such as felling of trees and farming within the grove. These latter actions are seen within the backdrop of the end of glass bead production and people's perception and reverence for the grove's deity.

Appendix A.2: Distribution of artifacts from Igbo Olokun (IO-TP1)

Levels	Pottery (Count)	Cylindrical Ceramic (Count)	Ceramics Disc (Count)	Baked Clay (Wt. g)	Glass Beads (Count)	Crucible Fragments (Count)	Glass Manufacturing Debris	Iron Objects (Count)	Slag (Count)	Bones (wt. gram.)
1	76					5				
2	256	7				12	5			4.1
3	167	1		30	26	9	16	1		
4	32	1		122	4	4	7			
5	208	4		220	19	9	21			
6	356	9	2	152	71	12	55	1	1	
6(Ft 1)	92	4	1		20	3	7	1		
Total	1187	26	3	524	140	54	111	3	1	4.1

Appendix A.3: Characteristics of Levels and Features in IO-TP 1 ([1]material was identified as vitrified production debris in 2011)

Levels	Depth (cm)	Color (Munsell)	Texture/Characteristics	Artifacts/Features	Dating Sample #
1	1-13	7.5 YR 3/3 Dark brown	Loose loam deposit with gravel inclusion. Lots of roots and rootlets with high humus content. Termite activities also noted.	Modern trash including plastic, broken glasses, rusted padlock, and broken electric bulb; potsherds; crucible fragments.	
2	13-25	7.5 3/3 Dark brown	Semi compact loam deposit with high gravel concentration. Termite disturbance along the north and south profiles.	Pottery, crucible fragments, cylindrical ceramics, Glass debris, and animal bones. Potsherds were bigger in size.	
3	25-30	5YR 3/3 Dark reddish brown	Compact gravelly deposit. Termite disturbance limited to the northern profile.	Potsherds, crucible fragments, cylindrical ceramic, glass beads, glass debris, baked clay, and iron object.	
4	25-35	7.5 YR 3/2 dark reddish brown	Loose loam deposit with less gravel inclusions. Restricted to the northwest sector of the unit.	Potsherds, crucible fragments, cylindrical ceramic, glass beads, glass debris, and baked clay.	
5	30-39	5YR 3/2 Dark reddish brown	Very compact clayey deposit. Hard to dig. There were animal burrows. Mica presence	Potsherds, crucible fragments, cylindrical ceramics, glass beads, glass debris, and baked clay.	TP1-01*

Appendix A.3: (Cont.) Characteristics of Levels and Features in IO-TP 1 ([1]material was identified as vitrified production debris in 2011)

Levels	Depth (cm)	Color (Munsell)	Texture/Characteristics	Artifacts/Features	Dating Sample #
6	39-52	5YR 3/3 Dark reddish brown	Slightly loose humic deposit with less gravelly inclusions	Potsherds, crucible fragments, cylindrical ceramics, ceramic disc, glass beads, glass debris, Iron object, slag[1], and baked clay. Feature 1 was noticed.	
6 (Feat.1)	52-80	5YR 3/3 Dark reddish brown	Pit feature. The fill was the same as level six.	Potsherds, crucible fragments, cylindrical ceramics, ceramic disc, glass beads, glass debris, and Iron object.	
7/8	52-90	5YR 5/6 Yellowish red	Compact homogeneous lateritic clay, with few gravel inclusions. Mica presence	Sterile	

*= Sample(s) analyzed for radiocarbon dating

Appendix A.4: Characteristics of Levels and Features in Unit IO-A ([1]material was identified as vitrified production debris in 2011)

Levels	Depth (cm)	Color (Munsell)	Texture/Characteristics	Artifacts/Features	Dating Sample #
1	1-25	HUE 7.5 YR 2.5/2 Very dark brown	Loose loam friable sand with gravel inclusion. Lots of roots and rootlets with inset burrow	Modern trash, potsherds, ceramic disc, cylindrical ceramics, crucible, porcelain, earthenware, glass beads, glass debris, and animal bones.	
2/3	25-43	HUE 7.5 3/2 Dark brown	Compact deposit with high gravel inclusion, and lots of quartz stones. Root and rootlets and burrow	Glass beads, glass debris, crucibles, potsherds, quartz flakes, grinding stone, stone bead, ceramics disc, vitrified production debris, baked clay, and snail shell.	05
4	43-52	HUE 7.5 YR 4/4 Brown	Semi compact clay loam deposit. Increase mica occurrence. Large roots and animal burrow.	Quartz flakes, Baked clay, crucible, cylindrical ceramics, potsherds, glass beads, glass debris, vitrified production debris, and animal bones	
5	52-67	HUE 5YR 3/2 Dark brown	Semi compact sandy loam, moist, Mica presence	Quartz stones, potsherds, glass beads, and glass debris	
6	67-78	HUE 5YR 3/3 Dark reddish brown	Very compact highly gravelly/stony; Iron stone deposit	Sterile	

Appendix A. 5: Artifacts Distributions by count in Units IO-A through IO-E and OO-A

Unit	Level	Potsherds	Porcelain/ Chinaware	Ceramic disc	Ceramic cylinder	Crucible Frag.	Baked clay/daub weight (gm.)	Iron Slag	Glass beads #	Glass debris weight (gm.)	Stones*	Stone beads	Cowrie Shell #	Snail shell weight (gm.)	Animal bones weight (gm.)
IO-A	1	348	3	1	7	14			95	16					
IO-A	2	101				4			70	11	2				
IO-A	3	972		2	20	25	15		505	136	5			1	
IO-A	4	160			7	4	242		198	40	3	2	1		9
IO-A	5	25							49	14					
Sub-Total		1606	3	3	34	47	257	0	917	217	10	2	1	1	9
IO-B	1	188			2	3			331	29			1		1
IO-B	2	89				6	10		191	29	1				6
IO-B	3	68	2			3	15		88	11		1			
IO-B	4	1250		6	48	57	462		1248	298	4			2	1
IO-B	5	349		1	15	27	203		221	64					4
IO-B	6	510		3	14	29	470		145	44	6				3
IO-B	7	430		1	14	35	100		184	76	1				
IO-B	8 (Pits 1 & 2)	588			20	50	284		59	35	1				
Sub-Total		3472	2	11	113	210	1544	0	2467	586	13	1	1	2	15

Appendix A. 5 (Cont.): Artifacts Distributions by count in Units IO-A through IO-E and OO-A

Unit	Level	Potsherds	Porcelain/ Chinaware	Ceramic disc	Ceramic cylinder	Crucible Frag.	Baked clay/daub weight (gm.)	Iron Slag	Glass beads #	Glass debris weight (gm.)	Stones*	Stone beads	Cowrie Shell #	Snail shell weight (gm.)	Animal bones weight (gm.)
IO-D	1	136			4	8			115	27					
IO-D	2	304	1	2	12	39	158		236	54	1			2	
IO-D	3	493		2	12	25	283		430	76	1				
IO-D	4	619		3	13	35	366		856	189	4				
IO-D	5	685			24	30	723		661	227	4				1
IO-D	6	994		1	42	106	1527		973	196	4				5
IO-D	7 (Pit 1)	38			2	5	41		53	8	2				
IO-D	7 (Pit 2)	228		3	9	43	3816		125	49	5				
Sub-Total		3497	1	11	118	291	6914	0	3449	826	21	0	0	2	6
IO-C	1	273	1		5	8	5		417	140					
IO-C	2	487		2	12	19			805	166				1	2
IO-C	3	382		1	12	18	35		451	86					
IO-C	4	1001		1	26	55	44		1437	298	1				2
IO-C	5	1611		4	43	74	231		1544	369	3				12

Appendix A. 5 (Cont.): Artifacts Distributions by count in Units IO-A through IO-E and OO-A

Unit	Level	Potsherds	Porcelain/ Chinaware	Ceramic disc	Ceramic cylinder	Crucible Frag.	Baked clay/daub weight (gm.)	Iron Slag	Glass beads #	Glass debris weight (gm.)	Stones*	Stone beads	Cowrie Shell #	Snail shell weight (gm.)	Animal bones weight (gm.)
IO-C	6	1253		2	28	73	61		945	250	2				2
IO-C	7	514			12	17	173		323	41	1				1.2
Sub-Total		5521	1	10	138	264	549	0	5922	1350	7	0		1	19.2
IO-E	1	404		3	4	8	80		16	6					
IO-E	2	634			5	31	76	1	66	11	1			5	
IO-E	3	428			2	15	30		24	3					
Sub-Total		1466		3	11	54	186	1	106	20	1	0		5	0
OO-A	1	524		4					4	1					
OO-A	2	1804		31	1	1	5		6	1	1				
OO-A	3	974		5					1						
OO-A	4	350		2			228		3	1					
OO-A	5	209													
OO-A	6	406		13											
OO-A	7	409		4	3	4	102								
Sub-Total		4676	0	59	4	5	335	0	14	3	1	0	0	0	0
Grand Total		20699	6	103	268	871	5740	1	12875	3006	54	3	2	11	45.4

Appendix A.6: Characteristics of Levels and Features in Unit IO-B/D

Level	Depth (cm)	Color (Munsell)	Texture/Characteristics	Artifacts/Features	C14 Sample #
1	1-15	10YR 2/2 Very Dark Brown	Loose loam friable soil. Roots and rootlets, insects burrow, and few to no gravel.	Modern trash including glass beads, crucibles, animal bones, lone cowrie, and potsherds	
2	15-22	5YR 3/2 Dark Reddish Brown	Loose loam soil with very few gravel and roots and rootlets.	Modern trash including plastic, metal straps, broken medicine bottles, with older materials such as potsherds, glass beads, glass debris, and crucible fragments cylindrical ceramics, vitrified production debris, and snail shell fragments	
3	22-27	7.5YR 4/3 Brown	Loose loam friable deposit high gravel concentration. Roots and rootlet and burrows	Potsherds, glass beads, glass debris, crucible fragments, cylindrical ceramics, ceramic disc, baked clay, quartz stones, and vitrified production debris	
4	27-45	5YR 4/3 Reddish Brown	Semi-compact clay-loam soil. Gravelly deposit with patches of fired clay. Level 2 deposit cut into this in the south. Fewer roots and rootlets.	Grinding stones, granites stones, pebbles, potsherds, cylindrical ceramics, ceramics disc, baked clay, crucible fragments, glass beads, glass debris, vitrified production debris, and animal bone fragments.	01
5	45-54	5YR 3/3 Dark Reddish Brown	Compact gravelly clayey deposit with gravel. Fire clay patches still evident, and level 2 cutting ended.	Crucible fragments, potsherds, cylindrical ceramics, baked clay, glass beads, glass debris, vitrified production debris, grinding stone fragments, and animal bones fragments.	07

Appendix A.6 (Cont.): Characteristics of Levels and Features in Unit IO-B/D

Level	Depth (cm)	Color (Munsell)	Texture/Characteristics	Artifacts/Features	C14 Sample #
6	54-68	7.5YR 4/3 Dark Brown	Semi compact clay-loam gravelly soil; moist and humic especially towards the western sector.	Baked clay, potsherds, ceramic disc, cylindrical ceramics, glass beads, glass debris, crucible fragments, quartz stones, muller, vitrified production debris, and animal bone fragments.	02, 03
7	68-90	7.5YR 3/3 Dark Brown	Loosely compact loam soil. Moist, gravelly, and humic deposit.	Baked clay, potsherds, ceramic disc, cylindrical ceramics, glass beads, glass debris, crucible fragments, stone fragments, vitrified production debris	04*, 08
8 (PitI)	90-123	5YR ¾ Dark Reddish Brown	Pit fill the same deposit as level 6 above.	Crucibles fragments, potsherds, cylinder ceramics, baked clay, quartz stones, glass beads, glass debris, and vitrified production debris.	06, 09, 10, 11
8 (PitII)	90-220	5YR 3/4 Dark Reddish Brown	Pit fill the same deposit as level 6 above.	Crucibles fragments, potsherds, cylinder ceramics, baked clay, quartz stones, glass beads, glass debris, vitrified production debris, granite slabs, grinding stones, and ceramic disc.	12
9	Sterile	5YR 5/6 Yellowish Red	Homogenous compact lateritic clay deposit. Unexcavated the pits were dug into this deposit.	Unexcavated	

*= Sample(s) analyzed for radiocarbon dating

Appendix A.7: Characteristics of Levels and Features in Unit IO-C

Level	Depth (cm)	Color (Munsell)	Texture/Characteristics	Artifacts/Features	C14 Sample #
1	1-23	10YR 3/3 Dark Brown	Very loose powdery loam sand with some gravel, roots, and rootlets	Modern trash, potsherds, Cylindrical ceramics, baked clay, earthenware, crucible, glass beads, and glass debris	
2	23-36	7.5YR 2.5/3 Very Dark Brown	Loose sandy soil with more gravel content and roots and rootlets. There were also insect burrows	Fewer modern trash, potsherds, cylindrical ceramics, ceramics disc, crucible, glass beads, glass debris, animal bones, and snail shell	
3	36-49	7.5 YR Dark Brown	Partial compact sand with low level of moisture. Lots of patches of red burnt clay. Still retain the gravelly character, and the occurrence of roots, rootlets, and animal/insect burrow	Mortar, baked clay, snail shell, ceramic disc, cylindrical ceramics, potsherds, crucibles, glass beads, and glass debris	13
4	49-64	7.5 YR 4/4 Brown	Mixture of semi compact and compact wet sand. High gravel content with patches of burnt clay. Roots and animal burrow also present	Animal bones, Stone, baked clay, cylindrical ceramics, ceramics disc, potsherds, crucible, glass beads, glass debris, and vitrified production debris	
5	64-96	7.5 YR 3/2 Dark Brown	Compact moist gravelly deposit. Burnt clay patches still present but along side charcoal patches.	Grinding stones, quartz stones, animal bones, baked clay, ceramics disc, cylindrical ceramics, crucible, potsherds, glass beads, glass debris, and vitrified production debris	14

Appendix A.7 (Cont.): Characteristics of Levels and Features in Unit IO-C

Level	Depth (cm)	Color (Munsell)	Texture/Characteristics	Artifacts/Features	C14 Sample #
6	96-118	7.5YR 3/3 Dark Brown	Dark semi compact moist gravelly sand. Burnt clay still occur	Grinding stone, quartz stone, baked clay, ceramics disc, cylindrical ceramics, potsherds, crucible, glass beads, glass debris, vitrified production debris, and animal bones	
7	118-127	7.5YR 3/2 Dark Brown	Dark less compact moist deposit with red clay occurrence in the southwest corner of the same level.	Hammer stone/muller, baked clay, cylindrical ceramics, crucible, potsherds, vitrified production debris, glass beads, glass debris, and animal bones	21*
8	131-135	5YR 3/3 Dark reddish brown	Very compact iron stone deposit. Level 7 continued in a depression from the north wall into the east wall	End of excavation	

*= Sample(s) analyzed for radiocarbon dating

Appendix A.8: Characteristics of Levels and Features in Unit IO-E

Level	Depth (cm)	Color (Munsell)	Texture/ Characteristics	Artifacts/Features	C14 Sample #
1	1-12	HUE 7.5 YR 2.5/2 Very Dark Brown	Loose dusty loam with few gravel properties and roots and rootlets	Modern trash, mortar, cemented potsherd	
2	12-32	HUE 7.5 YR 4/2 Brown	Loose friable dusky sand with more gravel content. Some roots and rootlets occur with animal burrow. Few burrows were noticeable in the profile. The profile were very fragile	Modern trash, lone slag	
3	32-59	HUE 7.5 YR 3/3 Dark Brown	Partially compact sand with lot of gravel. Insect/animal burrow still present	Crucible and potsherds. Materials reduced and total absent in the last 5 cm in this level.	
4	59-75	HUE 5YR 3/3 Dark reddish brown	Impenetrable iron stone deposit. The deposit was irregular across the unit. Thus, it's higher along the east wall and much deeper in the west	Sterile	

Appendix A.9: Characteristics of Levels and Features in Unit OO-A

Level	Depth (cm)	Color (Munsell)	Texture/ Characteristics	Artifacts/Features	C14 Sample #
1	1-11	2.5 YR 3/3 Dark Reddish Brown	Compact clay loam, dusty when sieving. There was low gravel content	Few modern trash, mostly potsherds, few glass beads, and some ceramics disc	
2	11-34	2.5 YR ¾ Dark Reddish Brown	Compact sandy clay with medium gravel content. However, still powdery when sieving	Abundance potsherds and ceramics disc, baked clay, lone crucible, muller, some glass beads with minute glass debris weight	
3	34-57	2.5 YR ¾ Dark Reddish Brown	Compact clay deposit with roots	Abundance of potsherds, ceramics disc, lone glass beads, (Lens 1 - hearth: located in the northeast corner. the matrix was mixture of ash and charcoal with lot of pottery concentration)	15, 16, 17
4	57-69	5 YR 4/6 Yellowish Red	Compact sticky clay with moderate moist. Roots are present	Potsherds, ceramics disc, baked clay, and fewer glass beads	18
5	69-75	2.5 YR Red	Compact sticky clay and hard to dig	Only potsherds but decreased compared to previous levels	
6	75-93	2.5 YR 4/6 Red	Semi compact clay with some gravel inclusions. Deposit was restricted to the eastern half of the unit	Mostly potsherds (more compared to level 5) with some ceramics disc. (Lens 2 – hearth 2: located along the east wall, spread about 46cm westward, and goes into the southeast corner meeting with loose dark soil lens. Ash, charcoal, and potsherds formed the lens matrix)	19, 20*
7	93-107	2.5 YR 4/6 Red	Compact sticky clay	Mostly potsherds, ceramics disc, and baked clay	
8	107-118	2.5 YR 4/6 Red	Compact sticky homogenous clay	Sterile	

*= Sample(s) analyzed for radiocarbon dating

Appendix A.10: Characteristics of Levels and Features in IR-TP 2

Level	Depth (cm)	Color (Munsell)	Texture/Characteristics	Artifacts/Features	Dating Sample #
1	1-11	5YR 3/2 Dark reddish brown	Loose loam rich humus content. Accumulation of decomposed leaves and tree stems on the surface and into the level.	Potsherds and snail shell fragments.	
2	11-18	5YR 3/3 Dark reddish brown	Semi-compact clay loam. Little or no humus content. A lot of roots and rootlets. Animal burrows encountered.	Potsherds, ceramic disc, bones, and baked clay. Materials increased in size and quantity.	TP2-01
3	18-26	5YR 3/3 Dark reddish brown	Semi-compact clay loam. Little or no humus content. A lot of roots and rootlets. Animal burrows encountered.	Potsherds, animal bone fragments, snail shell fragments, and baked clay.	
4	26-40	5YR 4/4 reddish brown	Loose loam midden deposit slight gravel inclusion. Animal burrows encountered.	Potsherds, baked clay, and animal bone fragments/jaw, oyster shell, snail shell (near complete), and palm kernels.	
5	40-47	5YR 3/3 Dark reddish brown/7.5 YR 3/2 dark reddish brown	Loose friable sandy loam midden, slight gravel inclusion. Roots presence, but no burrow.	Potsherds, baked clay, and animal bone fragments, complete snail shell and fragments.	
6	47-57	7.5 YR 2.5/3 very dark brown/ 7.5 YR 3/2 dark reddish brown	Loam midden deposit, slight gravel inclusion. Roots presence, but no burrow.	Potsherds, Iron object, baked clay, ceramic disc, animal bone fragments/jaws, and complete snail shell/fragments.	TP2-02

Appendix A.10 (Cont.): Characteristics of Levels and Features in IR-TP 2

Level	Depth (cm)	Color (Munsell)	Texture/Characteristics	Artifacts/Features	Dating Sample #
7	57-64	5YR 4/4 reddish brown	Loose loam midden deposit slight gravel inclusion. Roots presence, but no burrow.	Potsherds, animal bone fragments, snail shell fragments, and baked clay.	TP2-03*
8	64-73	10YR 3/4 Dusky red/7.5 YR 3/2 dark reddish brown	Semi compact loose loam with some clayey property.	Pottery, baked clay, animal bone fragments, and cowrie shell.	
9	73-90	10YR 3/4 Dusky red	Very compact homogeneous lateritic clay.	Sterile	

*= Sample(s) analyzed for radiocarbon dating

Appendix A.11: Distribution of artifacts from Igbo-Rudi (IR-TP 2)

Levels	Pottery (Count)	Ceramic Disc (Count)	Baked Clay (Wt. g)	Bones (Wt. g)	Snail Shell (Wt. g)	Tortoise Shell (Count)	Oyster Shell (Count)	Cowrie (Count)	Glass Beads (Count)	Iron Objects (Count)
1	59				4					
2	113	1	40	16						
3	80		158	24	4					
4	104			43	30		1			
5	75		121		28					
6	187	2	159	10	20	4	1			
7	128		612	22	20	9				1
8	72		186	4	1	3		1	1	
Total	818	3	1276	119	107	16	2	1	1	1

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Darden Hood
President

Ronald Hatfield
Christopher Patrick
Deputy Directors

April 19, 2011

Dr. Abidemi Babtunde Babalola
Rice University
Department of Anthropology
MS 20
6100 Main Street
Houston, TX 77005-1892
USA

RE: Radiocarbon Dating Result For Sample 1GOLTP1L5#2

Dear Dr. Babalola:

Enclosed is the radiocarbon dating result for one sample recently sent to us. It provided plenty of carbon for an accurate measurement and the analysis proceeded normally. The report sheet contains the method used, material type, and applied pretreatments and, where applicable, the two-sigma calendar calibration range.

This report has been both mailed and sent electronically. All results (excluding some inappropriate material types) which are less than about 20,000 years BP and more than about ~250 BP include a calendar calibration page (also digitally available in Windows metafile (.wmf) format upon request). Calibration is calculated using the newest (2004) calibration database with references quoted on the bottom of the page. Multiple probability ranges may appear in some cases, due to short-term variations in the atmospheric 14C contents at certain time periods. Examining the calibration graph will help you understand this phenomenon. Don't hesitate to contact us if you have questions about calibration.

We analyzed this sample on a sole priority basis. No students or intern researchers who would necessarily be distracted with other obligations and priorities were used in the analysis. We analyzed it with the combined attention of our entire professional staff.

Information pages are also enclosed with the mailed copy of this report. If you have any specific questions about the analysis, please do not hesitate to contact us. Someone is always available to answer your questions.

The cost of the analysis was charged to the MASTERCARD card provided. As always, if you have any questions or would like to discuss the results, don't hesitate to contact me.

Sincerely,

Darden Hood
Digital signature on file

BETA

BETA ANALYTIC INC.

DR. M.A. TAMERS and MR. D.G. HOOD

4985 S.W. 74 COURT
MIAMI, FLORIDA, USA 33155
PH: 305-667-5167 FAX:305-663-0964
beta@radiocarbon.com

REPORT OF RADIOCARBON DATING ANALYSES

Dr. Abidemi Babtunde Babalola — Report Date: 4/19/2011

Rice University — Material Received: 4/8/2011

Sample Data	Measured Radiocarbon Age	13C/12C Ratio	Conventional Radiocarbon Age(*)
Beta - 297164	130 +/- 30 BP	-24.6 o/oo	140 +/- 30 BP

SAMPLE : 1GOLTP1L5#2
ANALYSIS : AMS-Standard delivery
MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid
2 SIGMA CALIBRATION : Cal AD 1670 to 1780 (Cal BP 280 to 160) AND Cal AD 1790 to 1960 (Cal BP 160 to 0)

Dates are reported as RCYBP (radiocarbon years before present, "present" = AD 1950). By international convention, the modern reference standard was 95% the 14C activity of the National Institute of Standards and Technology (NIST) Oxalic Acid (SRM 4990C) and calculated using the Libby 14C half-life (5568 years). Quoted errors represent 1 relative standard deviation statistics (68% probability) counting errors based on the combined measurements of the sample, background, and modern reference standards. Measured 13C/12C ratios (delta 13C) were calculated relative to the PDB-1 standard.

The Conventional Radiocarbon Age represents the Measured Radiocarbon Age corrected for isotopic fractionation, calculated using the delta 13C. On rare occasion where the Conventional Radiocarbon Age was calculated using an assumed delta 13C, the ratio and the Conventional Radiocarbon Age will be followed by "*". The Conventional Radiocarbon Age is not calendar calibrated. When available, the Calendar Calibrated result is calculated from the Conventional Radiocarbon Age and is listed as the "Two Sigma Calibrated Result" for each sample.

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-24.6:lab. mult=1)

Laboratory number: **Beta-297164**

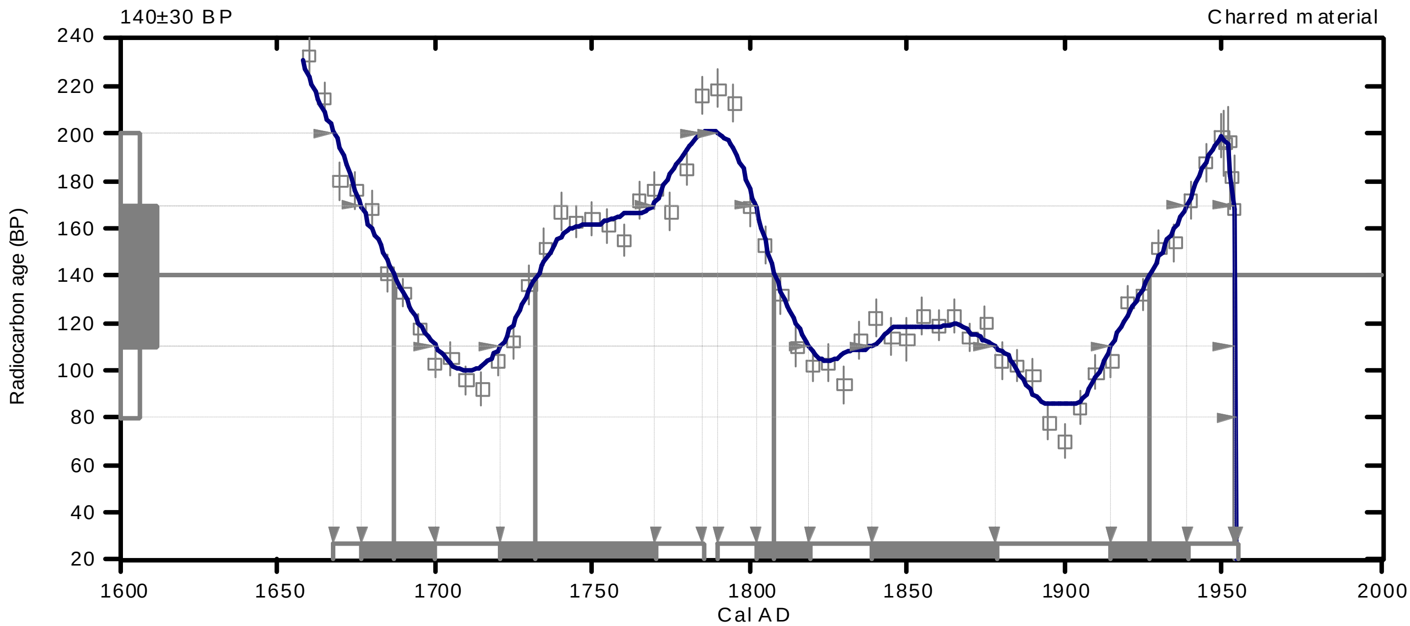
Conventional radiocarbon age: **140±30 BP**

2 Sigma calibrated results: **Cal AD 1670 to 1780 (Cal BP 280 to 160) and**
(95% probability) **Cal AD 1790 to 1960 (Cal BP 160 to 0)**

Intercept data

Intercepts of radiocarbon age
with calibration curve: Cal AD 1690 (Cal BP 260) and
Cal AD 1730 (Cal BP 220) and
Cal AD 1810 (Cal BP 140) and
Cal AD 1930 (Cal BP 20) and
Cal AD 1950 (Cal BP 0)

1 Sigma calibrated results: Cal AD 1680 to 1700 (Cal BP 270 to 250) and
(68% probability) Cal AD 1720 to 1770 (Cal BP 230 to 180) and
Cal AD 1800 to 1820 (Cal BP 150 to 130) and
Cal AD 1840 to 1880 (Cal BP 110 to 70) and
Cal AD 1920 to 1940 (Cal BP 40 to 10) and
Cal AD 1950 to 1950 (Cal BP 0 to 0)



References:

Database used
INTCAL04
Calibration Database
INTCAL04 Radiocarbon Age Calibration
IntCal04: Calibration Issue of Radiocarbon (Volume 46, nr 3, 2004).
Mathematics
A Simplified Approach to Calibrating C14 Dates
Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2), p317-322

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Darden Hood
President

Ronald Hatfield
Christopher Patrick
Deputy Directors

April 6, 2012

Dr. Abidemi Babtunde Babalola
Rice University
Department of Anthropology
MS 20
6100 Main Street
Houston, TX 77005-1892

RE: Radiocarbon Dating Results For Samples IGOLUTBL7#04, IGOLUTCL7#21, IGOLUTDL7#12, IGOLUTOAL620

Dear Dr. Babalola:

Enclosed are the radiocarbon dating results for four samples recently sent to us. They each provided plenty of carbon for accurate measurements and all the analyses proceeded normally. As usual, the method of analysis is listed on the report with the results and calibration data is provided where applicable.

As always, no students or intern researchers who would necessarily be distracted with other obligations and priorities were used in the analyses. We analyzed them with the combined attention of our entire professional staff.

If you have specific questions about the analyses, please contact us. We are always available to answer your questions.

The cost of the analysis was charged to the MASTERCARD card provided. A receipt is enclosed with the mailed report copy . Thank you. As always, if you have any questions or would like to discuss the results, don't hesitate to contact me.

Sincerely,

Darden Hood
Digital signature on file

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BETA ANALYTIC INC.

DR. M.A. TAMERS and MR. D.G. HOOD

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MIAMI, FLORIDA, USA 33155
PH: 305-667-5167 FAX:305-663-0964
beta@radiocarbon.com

REPORT OF RADIOCARBON DATING ANALYSES

Dr. Abidemi Babtunde Babalola — Report Date: 4/6/2012

Rice University — Material Received: 3/29/2012

Sample Data	Measured Radiocarbon Age	13C/12C Ratio	Conventional Radiocarbon Age(*)
Beta - 319447 SAMPLE : IGOLUTBL7#04 ANALYSIS : AMS-Standard delivery MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid 2 SIGMA CALIBRATION : Cal AD 1160 to 1260 (Cal BP 790 to 690)	860 +/- 30 BP	-26.0 o/oo	840 +/- 30 BP
Beta - 319448 SAMPLE : IGOLUTCL7#21 ANALYSIS : AMS-Standard delivery MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid 2 SIGMA CALIBRATION : Cal AD 1300 to 1360 (Cal BP 640 to 590) AND Cal AD 1380 to 1420 (Cal BP 570 to 530)	540 +/- 30 BP	-23.1 o/oo	570 +/- 30 BP
Beta - 319449 SAMPLE : IGOLUTDL7#12 ANALYSIS : AMS-Standard delivery MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid 2 SIGMA CALIBRATION : Cal AD 1690 to 1730 (Cal BP 260 to 220) AND Cal AD 1810 to 1920 (Cal BP 140 to 30) Cal AD Post 1950	100 +/- 30 BP	-26.6 o/oo	70 +/- 30 BP
Beta - 319450 SAMPLE : IGOLUTOAL620 ANALYSIS : AMS-Standard delivery MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid 2 SIGMA CALIBRATION : Cal AD 1290 to 1410 (Cal BP 660 to 540)	610 +/- 30 BP	-25.2 o/oo	610 +/- 30 BP

Dates are reported as RCYBP (radiocarbon years before present, "present" = AD 1950). By international convention, the modern reference standard was 95% the 14C activity of the National Institute of Standards and Technology (NIST) Oxalic Acid (SRM 4990C) and calculated using the Libby 14C half-life (5568 years). Quoted errors represent 1 relative standard deviation statistics (68% probability) counting errors based on the combined measurements of the sample, background, and modern reference standards. Measured 13C/12C ratios (delta 13C) were calculated relative to the PDB-1 standard.

The Conventional Radiocarbon Age represents the Measured Radiocarbon Age corrected for isotopic fractionation, calculated using the delta 13C. On rare occasion where the Conventional Radiocarbon Age was calculated using an assumed delta 13C, the ratio and the Conventional Radiocarbon Age will be followed by "*". The Conventional Radiocarbon Age is not calendar calibrated. When available, the Calendar Calibrated result is calculated from the Conventional Radiocarbon Age and is listed as the "Two Sigma Calibrated Result" for each sample.

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-26:lab. mult=1)

Laboratory number: **Beta-319447**

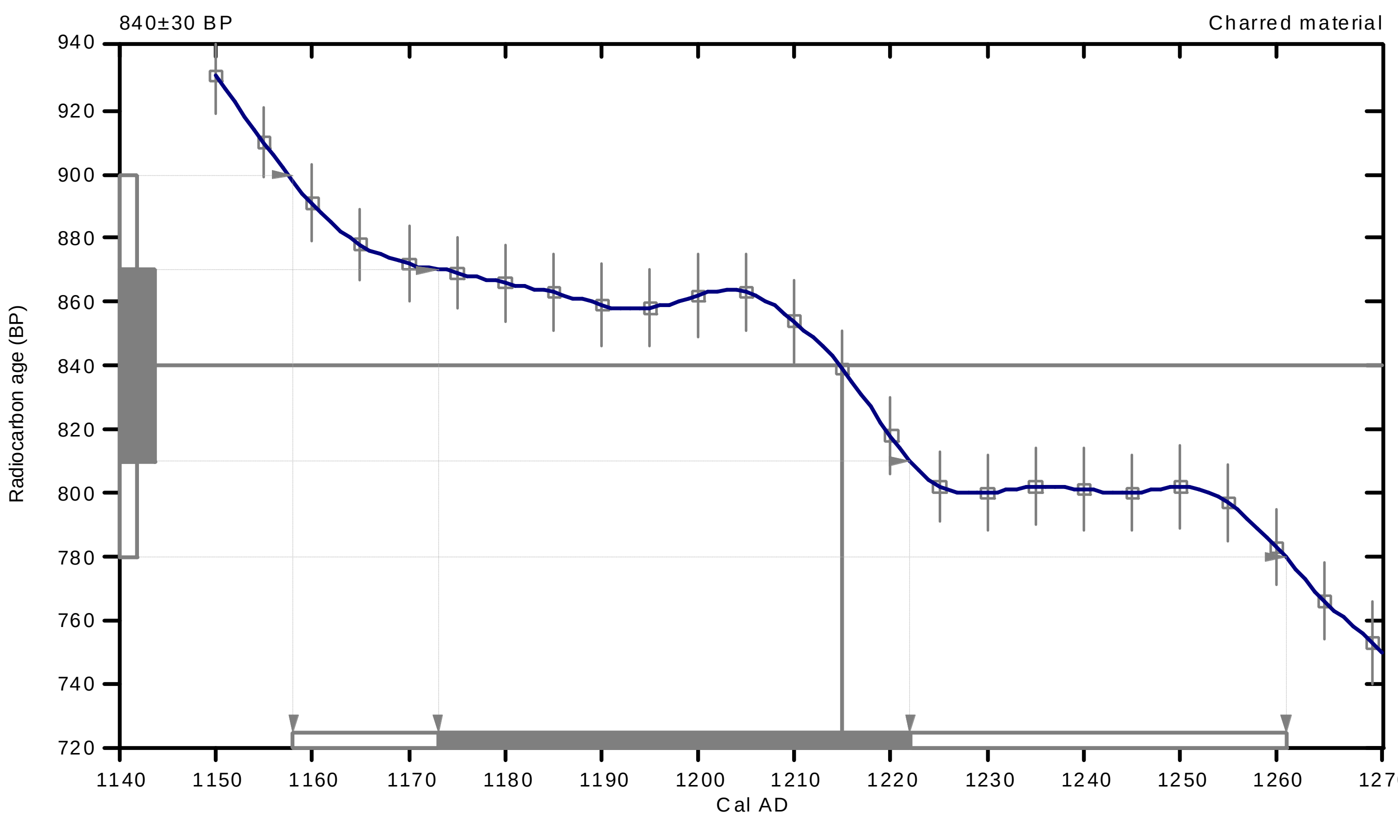
Conventional radiocarbon age: **840±30 BP**

2 Sigma calibrated result: (95% probability) **Cal AD 1160 to 1260 (Cal BP 790 to 690)**

Intercept data

Intercept of radiocarbon age with calibration curve: Cal AD 1220 (Cal BP 740)

1 Sigma calibrated result: (68% probability) Cal AD 1170 to 1220 (Cal BP 780 to 730)



References:

Database used

INTCAL09

References to INTCAL09 database

Heaton,et.al.,2009, Radiocarbon 51(4):1151-1164, Reimer,et.al, 2009, Radiocarbon 51(4):1111-1150, Stuiver,et.al,1993, Radiocarbon 35(1):137-189, Oeschger,et.al.,1975,Tellus 27:168-192

Mathematics used for calibration scenario

A Simplified Approach to Calibrating C14 Dates

Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2):317-322

Beta Analytic Radiocarbon Dating Laboratory

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CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-23.1:lab. mult=1)

Laboratory number: **Beta-319448**

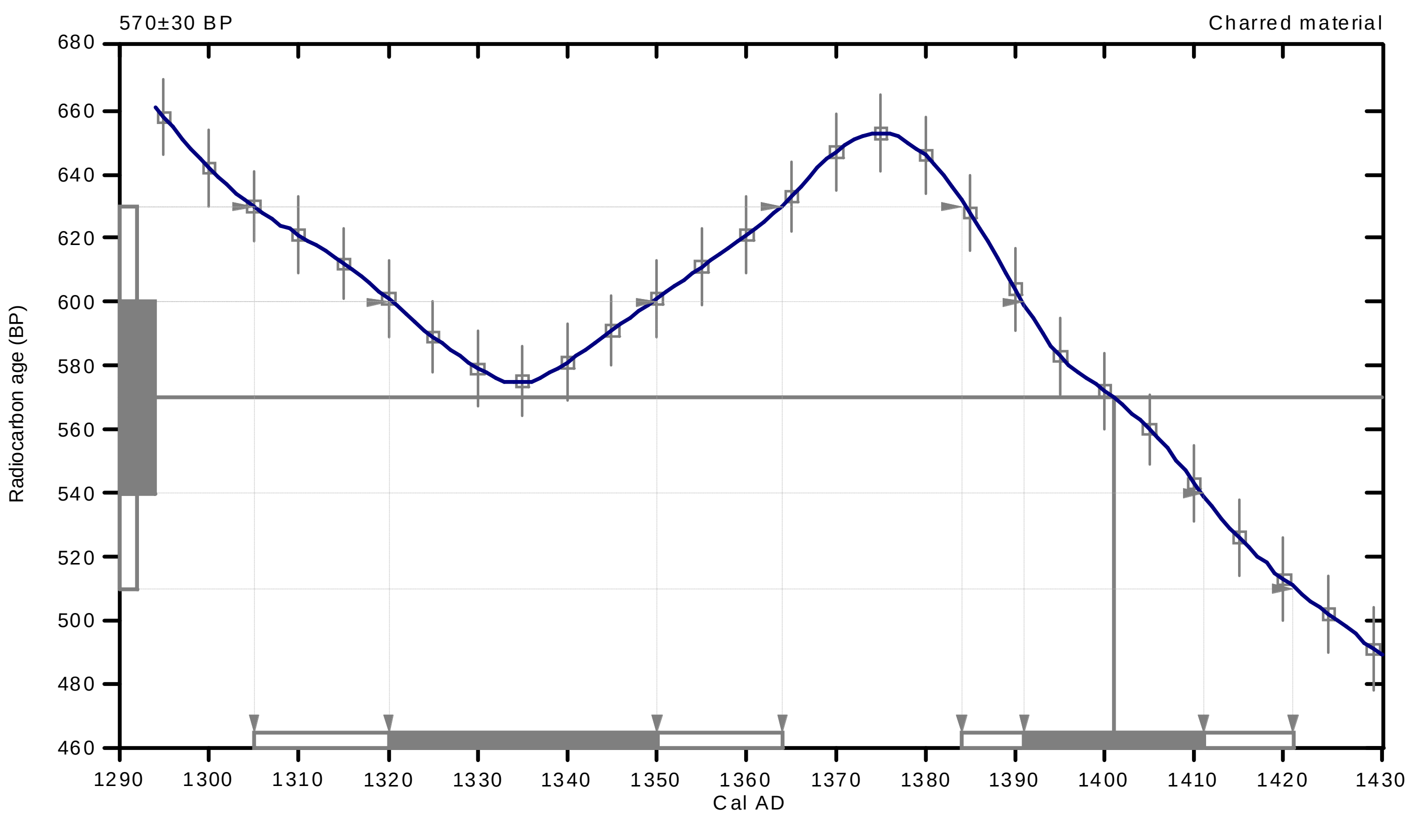
Conventional radiocarbon age: **570±30 BP**

2 Sigma calibrated results: **Cal AD 1300 to 1360 (Cal BP 640 to 590) and**
(95% probability) **Cal AD 1380 to 1420 (Cal BP 570 to 530)**

Intercept data

Intercept of radiocarbon age
with calibration curve: Cal AD 1400 (Cal BP 550)

1 Sigma calibrated results: Cal AD 1320 to 1350 (Cal BP 630 to 600) and
(68% probability) Cal AD 1390 to 1410 (Cal BP 560 to 540)



References:

Database used
INTCAL09

References to INTCAL09 database
Heaton,et.al.,2009, Radiocarbon 51(4):1151-1164, Reimer,et.al, 2009, Radiocarbon 51(4):1111-1150, Stuiver,et.al,1993, Radiocarbon 35(1):137-189, Oeschger,et.al.,1975,Tellus 27:168-192
Mathematics used for calibration scenario
A Simplified Approach to Calibrating C14 Dates
Talma, A. S., Vogel, J. C., 1993, Radiocarbon 35(2):317-322

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CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-26.6:lab. mult=1)

Laboratory number: **Beta-319449**

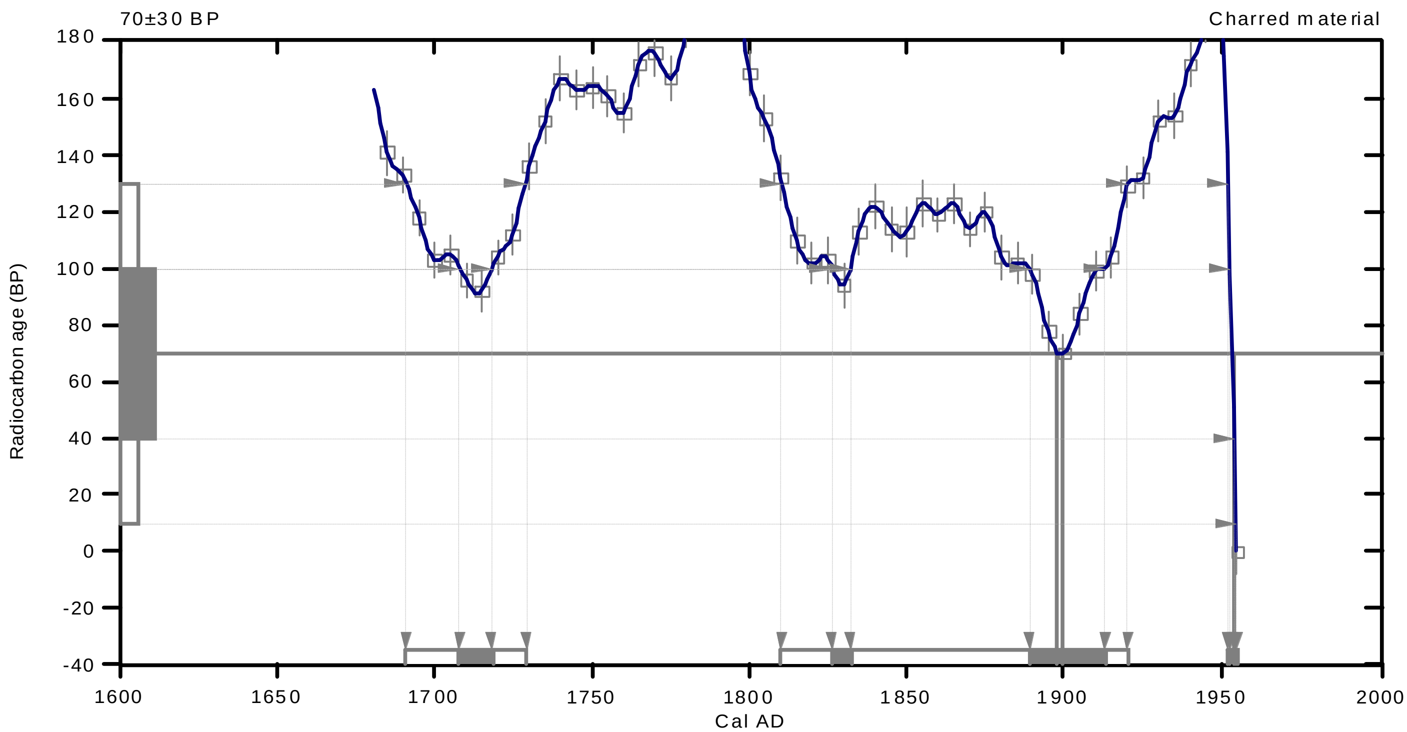
Conventional radiocarbon age: **70±30 BP**

2 Sigma calibrated results: (95% probability) **Cal AD 1690 to 1730 (Cal BP 260 to 220) and Cal AD 1810 to 1920 (Cal BP 140 to 30) and Cal AD Post 1950**

Intercept data

Intercepts of radiocarbon age with calibration curve: Cal AD 1900 (Cal BP 50) and Cal AD 1900 (Cal BP 50) and Cal AD Post 1950

1 Sigma calibrated results: (68% probability) Cal AD 1710 to 1720 (Cal BP 240 to 230) and Cal AD 1830 to 1830 (Cal BP 120 to 120) and Cal AD 1890 to 1910 (Cal BP 60 to 40) and Cal AD Post 1950



References:

Database used
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References to INTCAL09 database
Heaton,et.al.,2009, Radiocarbon 51(4):1151-1164, Reimer,et.al, 2009, Radiocarbon 51(4):1111-1150, Stuiver,et.al,1993, Radiocarbon 35(1):137-189, Oeschger,et.al.,1975,Tellus 27:168-192
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CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-25.2:lab. mult=1)

Laboratory number: **Beta-319450**

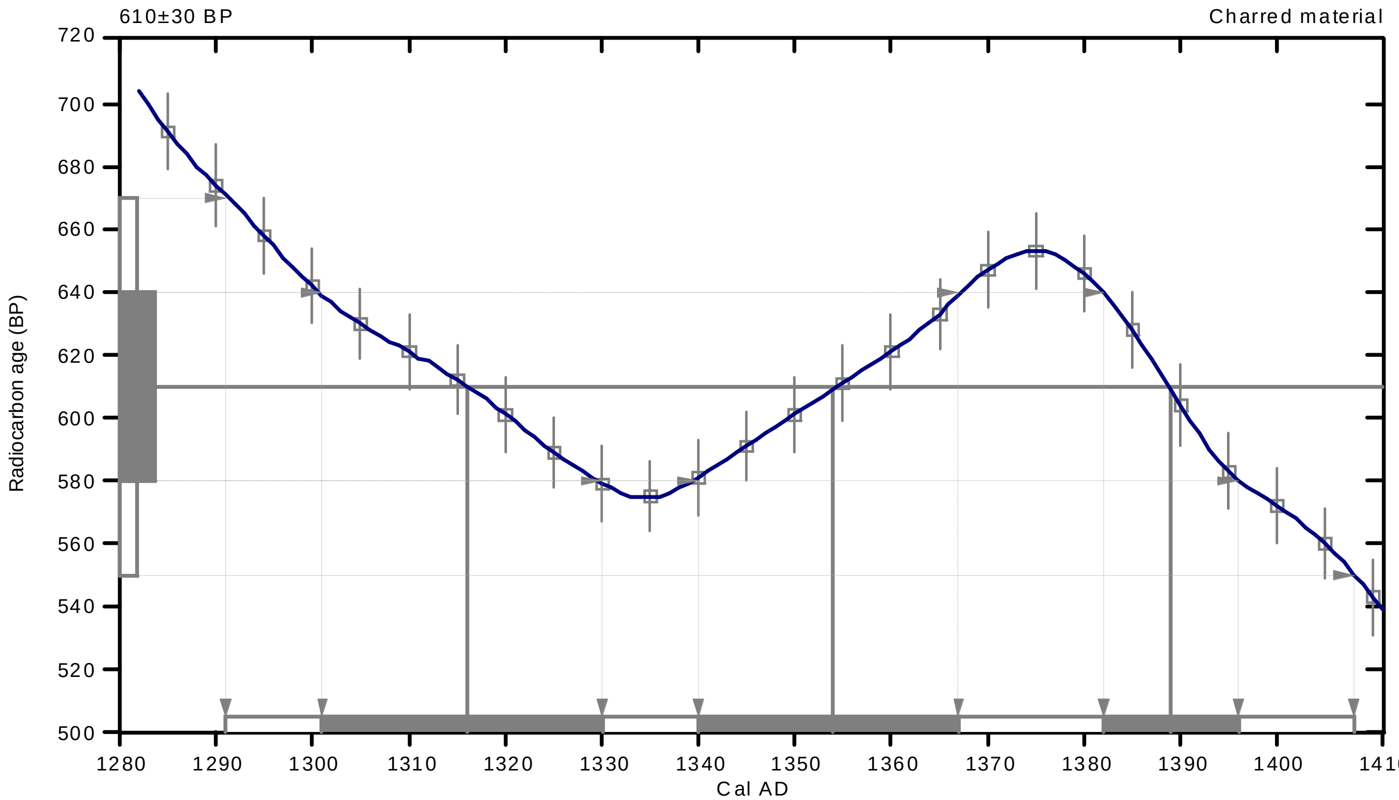
Conventional radiocarbon age: **610±30 BP**

2 Sigma calibrated result: (95% probability) **Cal AD 1290 to 1410 (Cal BP 660 to 540)**

Intercept data

Intercepts of radiocarbon age with calibration curve: Cal AD 1320 (Cal BP 630) and
Cal AD 1350 (Cal BP 600) and
Cal AD 1390 (Cal BP 560)

1 Sigma calibrated results: (68% probability) Cal AD 1300 to 1330 (Cal BP 650 to 620) and
Cal AD 1340 to 1370 (Cal BP 610 to 580) and
Cal AD 1380 to 1400 (Cal BP 570 to 550)



References:

Database used

INTCAL09

References to INTCAL09 database

Heaton,et.al.,2009, Radiocarbon 51(4):1151-1164, Reimer,et.al, 2009, Radiocarbon 51(4):1111-1150, Stuiver,et.al,1993, Radiocarbon 35(1):137-189, Oeschger,et.al.,1975,Tellus 27:168-192

Mathematics used for calibration scenario

A Simplified Approach to Calibrating C14 Dates

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Darden Hood
President

Ronald Hatfield
Christopher Patrick
Deputy Directors

October 9, 2013

Dr. Abidemi Babtunde Babalola
Rice University
Department of Anthropology
MS 20
6100 Main Street
Houston, TX 77005-1892
USA

RE: Radiocarbon Dating Result For Sample IGRDTP2L7#4

Dear Dr. Babalola:

Enclosed is the radiocarbon dating result for one sample recently sent to us. The sample provided plenty of carbon for accurate measurement and the analysis proceeded normally. As usual, the method of analysis is listed on the report with the results and calibration data is provided where applicable.

The web directory containing the table of all your results and PDF download also contains pictures including, most importantly the portion actually analyzed. These can be saved by opening them and right clicking. Also a cvs spreadsheet download option is available and a quality assurance report is posted for each set of results. This report contains expected versus measured values for 3-5 working standards analyzed simultaneously with your sample.

The reported result is accredited to ISO-17025 standards and the analysis was performed entirely here in our laboratories. Since Beta is not a teaching laboratory, only graduates trained in accordance with the strict protocols of the ISO-17025 program participated in the analyses. When interpreting the result, please consider any communications you may have had with us regarding the sample.

If you have specific questions about the analyses, please contact us. Your inquiries are always welcome.

The cost of the analysis was charged to the MASTERCARD card provided. Thank you. As always, if you have any questions or would like to discuss the results, don't hesitate to contact me.

Sincerely,

Darden Hood
Digital signature on file

BETA ANALYTIC INC.
DR. M.A. TAMERS and MR. D.G. HOOD
4985 S.W. 74 COURT
MIAMI, FLORIDA, USA 33155
PH: 305-667-5167 FAX:305-663-0964
beta@radiocarbon.com

REPORT OF RADIOCARBON DATING ANALYSES

Dr. Abidemi Babtunde Babalola — Report Date: 10/9/2013

Rice University — Material Received: 10/4/2013

Sample Data	Measured Radiocarbon Age	13C/12C Ratio	Conventional Radiocarbon Age(*)
Beta - 361087	300 +/- 30 BP	-26.3 o/oo	280 +/- 30 BP

SAMPLE : IGRDTP2L7#4
ANALYSIS : AMS-Standard delivery
MATERIAL/PRETREATMENT : (charred material): acid/alkali/acid
2 SIGMA CALIBRATION : Cal AD 1520 to 1590 (Cal BP 430 to 360) AND Cal AD 1620 to 1660 (Cal BP 330 to 290)

Dates are reported as RCYBP (radiocarbon years before present, "present" = AD 1950). By international convention, the modern reference standard was 95% the 14C activity of the National Institute of Standards and Technology (NIST) Oxalic Acid (SRM 4990C) and calculated using the Libby 14C half-life (5568 years). Quoted errors represent 1 relative standard deviation statistics (68% probability) counting errors based on the combined measurements of the sample, background, and modern reference standards. Measured 13C/12C ratios (delta 13C) were calculated relative to the PDB-1 standard.

The Conventional Radiocarbon Age represents the Measured Radiocarbon Age corrected for isotopic fractionation, calculated using the delta 13C. On rare occasion where the Conventional Radiocarbon Age was calculated using an assumed delta 13C, the ratio and the Conventional Radiocarbon Age will be followed by "*". The Conventional Radiocarbon Age is not calendar calibrated. When available, the Calendar Calibrated result is calculated from the Conventional Radiocarbon Age and is listed as the "Two Sigma Calibrated Result" for each sample.

CALIBRATION OF RADIOCARBON AGE TO CALENDAR YEARS

(Variables: C13/C12=-26.3:lab. mult=1)

Laboratory number: **Beta-361087**

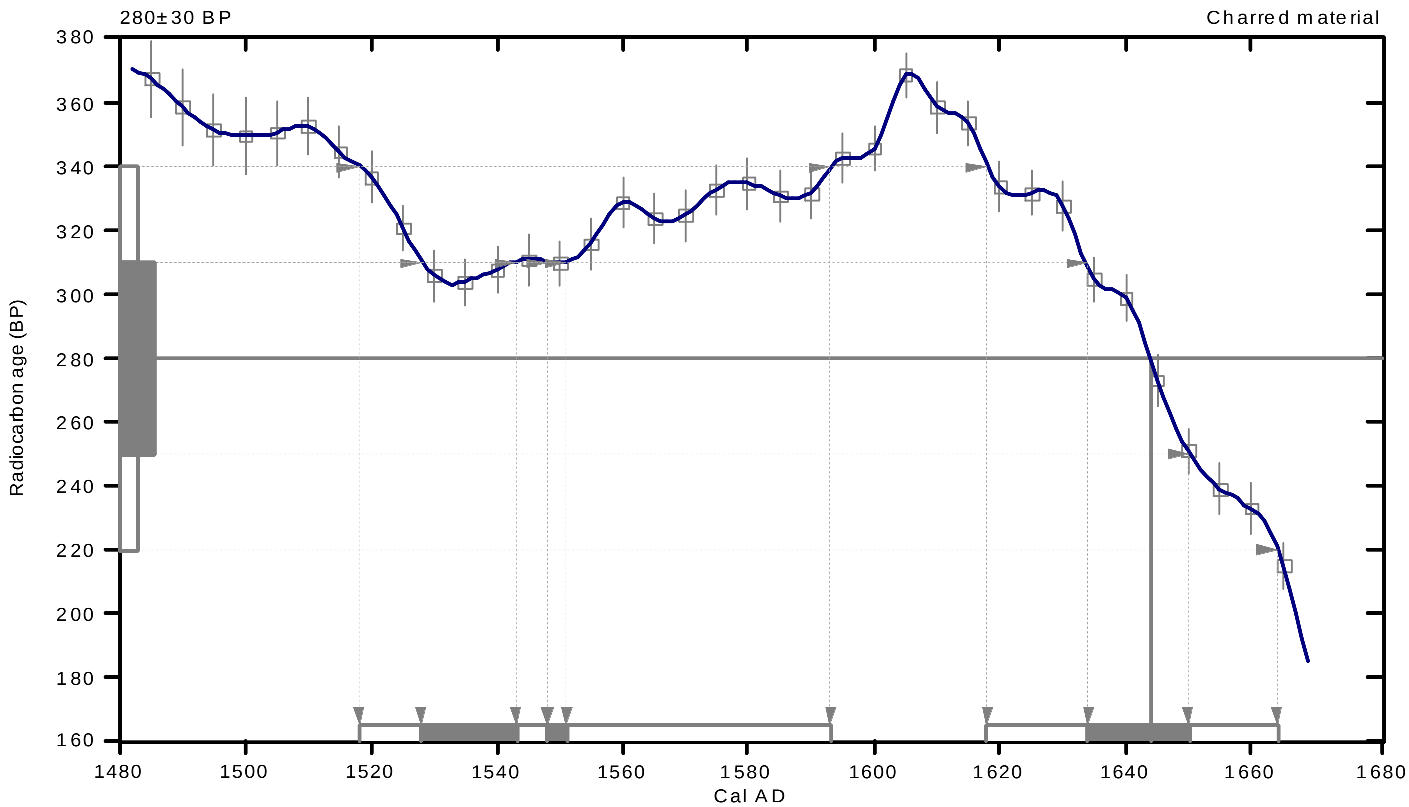
Conventional radiocarbon age: **280±30 BP**

2 Sigma calibrated results: **Cal AD 1520 to 1590 (Cal BP 430 to 360) and**
(95% probability) **Cal AD 1620 to 1660 (Cal BP 330 to 290)**

Intercept data

Intercept of radiocarbon age
with calibration curve: Cal AD 1640 (Cal BP 310)

1 Sigma calibrated results: Cal AD 1530 to 1540 (Cal BP 420 to 410) and
(68% probability) Cal AD 1550 to 1550 (Cal BP 400 to 400) and
Cal AD 1630 to 1650 (Cal BP 320 to 300)



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Appendix A. 13

LUMINESCENCE ANALYSIS OF CRUCIBLE FRAGMENTS FROM NIGERIA

15 April 2015

James K. Feathers
Luminescence Dating Laboratory
University of Washington
Seattle, WA 98195-3412
Email: jimf@u.washington.edu

This report presents the results of luminescence analysis on 5 glass-making ceramic crucible fragments from ancient Ile-Ife, southwest Nigeria. The samples were, submitted by Abidemi Babatunde Babalola, Rice University. The ceramics contain coarse quartz temper that has fused to the clay matrix. Table 1 lists the samples and depths. Laboratory procedures are given in the appendix.

Table 1. Samples

UW Lab #	Sample #	Depth (cm)
UW3020	IGOLTAL4/01	70-90
UW3021	IGOLUTBDL5/02	51-60
UW3022	IGOLUTBDL6/03	68-90
UW3023	IGOLUTBDL6/04	68-90
UW3024	IGOLUTCL7/05	118-127

Dose rate

The dose rate was measured on each ceramic and associated sediment. Dose rates were mainly determined using alpha counting and flame photometry. The beta dose rate calculated from these measurements on the ceramics was compared with the beta dose rate measured directly by beta counting. These were within 1-sigma error terms for all samples, except UW3021, although the results from beta counting were systematically higher for all samples. This could mean some depletion of daughters in the U decay chain, if the parent ^{238}U had relatively recently been absorbed into the ceramics. The granitic bedrock at this site is linked to higher U contents. Plus, the U contents in the ceramic samples are higher than the Th contents, when usually Th is about three times more abundant. Notice the large difference in U/Th ratio between the ceramics and the adjacent sediments. This suggests that U uptake may have occurred. However, it is not expected to be very significant, because the dose rates are dominated by beta radiation from ^{40}K. Even if all the U in the samples is due to recent uptake (not likely), the ages would only be reduced by about 20%, or 500 years for a 2500 year-old sample. Ceramic moisture content was estimated as 80 ± 30 % of saturated value. This is based on Nigeria's humid climate, but it may be over-estimated. However, the effect on the final age will be slight, because saturated values are only 4-8 % for these samples. For associated sediments, the moisture content was estimated at 15 ± 5%. Cosmic dose radiation was calculated as explained in the appendix. Table 2 gives the radioactivity data and comparison of the beta dose rate calculated in the two ways mentioned. Table 3 gives total dose rates for each sample.

Table 2. Radionuclide concentrations

Sample	^{238}U *(ppm)*	^{233}Th *(ppm)*	*K (%)*	*Beta dose rate (Gy/ka)*	
				ß-counting	α-counting/flame photometry
UW3020	2.97±0.17	2.03±0.61	3.32±0.13	3.61±0.30	3.22±0.11
sediment	2.57±0.22	12.39±1.37	0.25±0.01		
UW3021	2.15±0.14	2.86±0.62	2.66±0.12	2.97±0.26	2.58±0.10
Sediment	1.01±0.14	9.74±1.24	0.38±0.01		
UW3022	4.69±0.25	1.71±0.61	3.57±0.26	3.80±0.34	3.66±0.22
Sediment	1.54±0.19	13.73±1.55	0.40±0.15		
UW3023	3.20±0.18	1.47±0.54	2.57±0.10	2.82±0.26	2.62±0.09
Sediment	1.21±0.11	4.95±0.88	0.16±0.01		
UW3024	1.44±0.09	0.67±0.31	2.37±0.09	2.41±0.21	2.17±0.08
Sediment	1.38±0.16	10.38±1.31	0.28±0.01		

Table 3. Dose rates (Gy/ka)*

Sample	*alpha*	*beta*	*gamma*	*cosmic*	*total*
UW3020	0.39±0.03	3.08±0.12	0.88±0.07	0.17±0.03	4.52±0.14
UW3021	0.32±0.03	2.82±0.25	0.64±0.06	0.18±0.04	3.96±0.26
UW3022	0.83±0.09	3.47±0.22	0.92±0.08	0.17±0.03	5.39±0.25
UW3023	0.55±0.05	2.45±0.10	0.44±0.04	0.17±0.03	3.61±0.13
UW3024	0.12±0.01	2.00±0.09	0.65±0.06	0.15±0.03	2.93±0.12

* Dose rates for ceramics are calculated for OSL. They will be higher for TL and IRSL due to higher b-values. Also the beta dose rate is lower than that given in Table 2 due to moisture correction.

Equivalent Dose

Equivalent dose was measured for TL, OSL and IRSL as described in the appendix. For UW3021, the TL signal did not increase with dose, so an equivalent dose was not possible to obtain. For the others, TL plateaus (Table 4) were relatively broad, but very narrow for UW3023. UW3023 was also the only sample to have a sensitivity change with heating. Scatter in the growth curves was high for all samples. TL anomalous fading was evident in all samples (not measured yet for UW3023). Measured fading rates (Table 4) were impossibly high. Rates that high would result in no signal at all, which was not observed. Fading rate must have changed through time, so no correction was possible.

Table 4. TL parameters

Sample	*Plateau (°C)*	*$1^{st}/2^{nd}$ ratio**	*fit*	*Fading g-value***
UW3020	290-350	1	linear	20.7±10.1
UW3022	250-370	1	quadratic	20.7±6.1
UW3023	310-330	0.69±0.10	linear	
UW3024	260-380	1	quadratic	21.9±8.6

*Refers to slope ratio between the first and second glow growth curves. A glow refers to luminescence as a function of temperature; a second glow comes after heating to 450°C.
** A g-value is a rate of anomalous fading, measured as percent of signal loss per decade, where a decade is a power of 10.

OSL/IRSL was measured on 6 aliquots per sample, although not all produced a measurable signal (Table 5). Scatter was high for UW3022. An IRSL signal could not be distinguished from background on UW3021, and only one aliquot produced a measurable IRSL signal on UW3020. Generally, the IRSL signal was about 5 to 8 times less intense than the OSL signal. Weak IRSL signals are not uncommon for ceramics. IRSL stems from feldspars, which are prone to anomalous fading. A relatively large IRSL signal may suggest the OSL signal partly stems from feldspars and therefore may fade, so a weak IRSL suggests the OSL is dominated by quartz. Moreover, the OSL b-value, which is a measure of the efficiency of alpha radiation in producing luminescence as compared to beta and gamma radiation, is in the typical range of quartz for UW3020, UW3021 and UW3024, and just a little higher for UW3022 and UW3023. Is not likely, therefore, that the OSL signal fades. As a test of the SAR procedures, a dose recovery test was performed on all sherds. The recovered dose was within one sigma of the given dose for four samples and within two sigma for UW3020. Equivalent dose and b-values for TL and OSL are given in Table 6.

Table 5. OSL/IRSL data

Sample	# aliquots*		OSL Over-dispersion (%)	Dose Recovery (OSL)	
	OSL	IRSL		Given Dose (sß)	Recovered Dose (sß)
UW3020	6	1	14±6	30	40.0±6.2
UW3021	5	0	10±4	40	39.2±3.3
UW3022	6	3	22±7	30	32.2±2.4
UW3023	2	2	0	30	29.2±1.5
UW3024	6	6	14±4	100	100±4.4

*Denotes aliquots with measurable signals

Table 6. Equivalent dose and b-value – fine grains

Sample	*Equivalent dose (Gy)*			*b-value (Gy µm^2)*		
	TL	*IRSL*	*OSL*	*TL*	*IRSL*	*OSL**
UW3020	23.3±4.77	6.00±1.96	17.9±1.19	2.19±0.76	1.44±0.43	0.66±0.04
UW3021			9.95±0.51			0.66±0. 6
UW3022	10.4±3.50	17.2±1.78	13.0±1.23	3.19±1.49	1.90±0.31	0.99±0.09
UW3023	13.5±2.14	13.0±2.62	2.30±0.18	0.69±0.14	0.86±0.14	0.94±0.08
UW3024	13.6±1.06	19.1±1.26	7.89±0.48	1.26±0.25	0.91±0.05	0.48±0.01

Ages

Ages are given in Table 7. For UW3020, the ages from OSL and TL (not corrected for fading) were in agreement. The IRSL age was younger, but probably suffers from fading. For UW3021, the OSL age was all that was available. For UW3022, the ages from OSL and IRSL agreed with each other. The TL age was younger but probably suffers from fading. For UW3023, the ages from IRSL and TL (not corrected for fading) were in agreement. The OSL age was much younger, and this will be discussed in a moment. For UW3023, the TL and IRSL ages were much older than the OSL age, which was taken as the best estimate.

All of these ages are much older than the expected age range of AD 500-1000. The only age data that fell anywhere near that range was the OSL age from UW3023: AD 1380 ± 60. This was based on only two aliquots (the other four aliquots from this sample would have fallen in the same range but were rejected because of failure to properly correct for sensitivity change). The

TL and IRSL ages were older for this sample, and no other data from any other sample supported this younger age. It is therefore rather anomalous.

I cannot think of a reason for the samples to be systematically old. I do not think, for reasons discussed earlier, that the dose rates are in error. The high heat that the crucibles were subject to should have zeroed the signals sufficiently. The OSL signals decayed fairly rapidly, so were not dominated by slow bleaching components. The analyses were all performed on fine-grained materials. Some coarse-grained material was obtained for UW3022. This material has not been analyzed yet, but it will be interesting to see if the result matches that from the fine grains.

Table 7. Ages

Sample	Age (ka)	% error	Basis for age	Calendar date
UW3020	3.99±0.30	7.6	Uncorrected TL/OSL	BC 1980 ± 300
UW3021	2.51±0.22	8.9	OSL	BC 500 ± 220
UW3022	2.55±0.21	8.2	IRSL/OSL	BC 540 ± 210
UW3023	3.81±0.49	13.0	IRSL/uncorrected TL	BC 1790 ± 490
UW3024	2.69±0.21	7.9	OSL	BC 680 ± 210

Appendix

Procedures for Thermoluminescence Analysis of Pottery

Sample preparation -- fine grain

The sherd is broken to expose a fresh profile. Material is drilled from the center of the cross-section, more than 2 mm from either surface, using a tungsten carbide drill tip. The material retrieved is ground gently by an agate mortar and pestle, treated with HCl, and then settled in acetone for 2 and 20 minutes to separate the 1-8 µm fraction. This is settled onto a maximum of 72 stainless steel discs.

Glow-outs

Thermoluminescence is measured by a Daybreak reader using a 9635Q photomultiplier with a Corning 7-59 blue filter, in N_2 atmosphere at 1°C/s to 450°C. A preheat of 240°C with no hold time precedes each measurement. Artificial irradiation is given with a ^{241}Am alpha source and a ^{90}Sr beta source, the latter calibrated against a ^{137}Cs gamma source. Discs are stored at room temperature for at least one week after irradiation before glow out. Data are processed by Daybreak TLApplic software.

Fading test

Several discs are used to test for anomalous fading. The natural luminescence is first measured by heating to 450°C. The discs are then given an equal alpha irradiation and stored at room temperature for varied times: 10 min, 2 hours, 1 day, 1 week and 8 weeks. The irradiations are staggered in time so that all of the second glows are performed on the same day. The second glows are normalized by the natural signal and then compared to determine any loss of signal with time (on a log scale). If the sample shows fading and the signal versus time values can be reasonably fit to a logarithmic function, an attempt is made to correct the age following procedures recommended by Huntley and Lamothe (2001). The fading rate is calculated as the g-value, which is given in percent per decade, where decade represents a power of 10.

Equivalent dose

The equivalent dose is determined by a combination additive dose and regeneration (Aitken 1985). Additive dose involves administering incremental doses to natural material. A growth curve plotting dose against luminescence can be extrapolated to the dose axis to estimate an equivalent dose, but for pottery this estimate is usually inaccurate because of errors in extrapolation due to nonlinearity. Regeneration involves zeroing natural material by heating to 450°C and then rebuilding a growth curve with incremental doses. The problem here is sensitivity change caused by the heating. By constructing both curves, the regeneration curve can be used to define the extrapolated area and can be corrected for sensitivity change by comparing it with the additive dose curve. This works where the shapes of the curves differ only in scale (i.e., the sensitivity change is independent of dose). The curves are combined using the "Australian slide" method in a program developed by David Huntley of Simon Fraser University (Prescott et al. 1993). The equivalent dose is taken as the horizontal distance between the two curves after a scale adjustment for sensitivity change. Where the growth curves are not linear, they are fit to quadratic functions. Dose increments (usually five) are determined so that the maximum additive dose results in a signal about three times that of the natural and the maximum regeneration dose about five times the natural.

A plateau region is determined by calculating the equivalent dose at temperature increments between 240° and 450°C and determining over which temperature range the values do not differ significantly. This plateau region is compared with a similar one constructed for the b-value (alpha efficiency), and the overlap defines the integrated range for final analysis.

Alpha effectiveness

Alpha efficiency is determined by comparing additive dose curves using alpha and beta irradiations. The slide program is also used in this regard, taking the scale factor (which is the ratio of the two slopes) as the b-value (Aitken 1985).

Radioactivity

Radioactivity is measured by alpha counting in conjunction with atomic emission for ^{40}K. Samples for alpha counting are crushed in a mill to flour consistency, packed into plexiglass containers with ZnS:Ag screens, and sealed for one month before counting. The pairs technique is used to separate the U and Th decay series. For atomic emission measurements, samples are dissolved in HF and other acids and analyzed by a Jenway flame photometer. K concentrations for each sample are determined by bracketing between standards of known concentration. Conversion to ^{40}K is by natural atomic abundance. Radioactivity is also measured, as a check, by beta counting, using a Risø low level beta GM multicounter system. About 0.5 g of crushed sample is placed on each of four plastic sample holders. All are counted for 24 hours. The average is converted to dose rate following Bøtter-Jensen and Mejdahl (1988) and compared with the beta dose rate calculated from the alpha counting and flame photometer results.

Both the sherd and an associated soil sample are measured for radioactivity. Additional soil samples are analyzed where the environment is complex, and gamma contributions determined by gradients (after Aitken 1985: appendix H). Cosmic radiation is determined after

Prescott and Hutton (1994). Radioactivity concentrations are translated into dose rates following Guérin et al. (2011).

Moisture Contents

Water absorption values for the sherds are determined by comparing the saturated and dried weights. For temperate climates, moisture in the pottery is taken to be 80 ± 20 percent of total absorption, unless otherwise indicated by the archaeologist. Again for temperate climates, soil moisture contents are taken from typical moisture retention quantities for different textured soils (Brady 1974: 196), unless otherwise measured. For drier climates, moisture values are determined in consultation with the archaeologist.

Procedures for Optically Stimulated or Infrared Stimulated Luminescence of Fine-grained pottery.

Optically stimulated luminescence (OSL) and infrared stimulated luminescence (IRSL) on fine-grain (1-8µm) pottery samples are carried out on single aliquots following procedures adapted from Banerjee et al. (2001) and Roberts and Wintle (2001. Equivalent dose is determined by the single-aliquot regenerative dose (SAR) method (Murray and Wintle 2000).

The SAR method measures the natural signal and the signal from a series of regeneration doses on a single aliquot. The method uses a small test dose to monitor and correct for sensitivity changes brought about by preheating, irradiation or light stimulation. SAR consists of the following steps: 1) preheat, 2) measurement of natural signal (OSL or IRSL), L(1), 3) test dose, 4) cut heat, 5) measurement of test dose signal, T(1), 6) regeneration dose, 7) preheat, 8) measurement of signal from regeneration, L(2), 9) test dose, 10) cut heat, 11) measurement of test dose signal, T(2), 12) repeat of steps 6 through 11 for various regeneration doses. A growth curve is constructed from the L(i)/T(i) ratios and the equivalent dose is found by interpolation of L(1)/T(1). Usually a zero regeneration dose and a repeated regeneration dose are employed to insure the procedure is working properly. For fine-grained ceramics, a preheat of 240°C for 10s, a test dose of 3.1 Gy, and a cut heat of 200°C are currently being used, although these parameters may be modified from sample to sample.

The luminescence, L(i) and T(i), is measured on a Risø TL-DA-15 automated reader by a succession of two stimulations: first 100 s at 60°C of IRSL (880nm diodes), and then 100s at 125°C of OSL (470nm diodes). Detection is through 7.5mm of Hoya U340 (ultra-violet) filters. The two stimulations are used to construct IRSL and OSL growth curves, so that two estimations of equivalent dose are available. Anomalous fading usually involves feldspars and only feldspars are sensitive to IRSL stimulation. The rationale for the IRSL stimulation is to remove most of the feldspar signal, so that the subsequent OSL (post IR blue) signal is free from anomalous fading. However, feldspar is also sensitive to blue light (470nm), and it is possible that IRSL does not remove all the feldspar signal. Some preliminary tests in our laboratory have suggested that the OSL signal does not suffer from fading, but this may be sample specific. The procedure is still undergoing study.

A dose recovery test is performed by first zeroing the sample by exposure to light and then administering a known dose. The SAR protocol is then applied to see if the known dose can be obtained.

Alpha efficiency will surely differ among IRSL, OSL and TL on fine-grained materials. It does differ between coarse-grained feldspar and quartz (Aitken 1985). Research is currently underway in the laboratory to determine how much b-value varies according to stimulation method. Results from several samples from different geographic locations show that OSL b-value is less variable and centers around 0.5. IRSL b-value is more variable and is higher than that for OSL. TL b-value tends to fall between the OSL and IRSL values. We currently are measuring the b-value for IRSL and OSL by giving an alpha dose to aliquots whose luminescence have been drained by exposure to light. An equivalent dose is determined by SAR using beta irradiation, and the beta/alpha equivalent dose ratio is taken as the b-value. A high OSL b-value is indicative that feldspars might be contributing to the signal and thus subject to anomalous fading.

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Age and error terms

The age and error for both OSL and TL are calculated by a laboratory constructed spreadsheet, based on Aitken (1985). All error terms are reported at 1-sigma.

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APPENDIX B

Appendix B.1: Rim recording sheet for Ile-Ife pottery

Unit
Level

Rim Diameter
- Recorded as is

Rim Thickness
- Recorded as is

Rim Angle
1. Tightly closed
2. Closed
3. Vertical
4. Open
5. Wide Open
6. Potlid

Rim Type
1- Simple
2- Thickened
3- Carinated
4- Ledged
5- Short Everted
6- Medium Everted
7- Long Everted
8- T-Rim/Out-turn
9- Beaded
10- Potlid
11- Miscellaneous

Lip Shape
1- Rounded
2- Flattened
3- Bevelled
4- Indented
5- Thickened
6- Angular
7- Tapered
8- Fluted
9- Flattened in-turn

Harness/Paste
1- Soft
2- Medium
3- Hard

Paste Color
1- Orange
2- Brown
3- Black/Gray
4- Buff

Core
0- Fully Oxidized
1- Exterior Oxidation only
2- Interior Oxidation only
3- Black Sandwiched
4- Black/Gray throughout
5- Sandwiched Oxidation

NPI Dominant
1- Quartz
2- Sand
3- Grog

NPI Other
1- Quartz
2- Sand
3- Grog

Mica
0- Absence
1- Heavy
2- Medium
3- Low

Surface Finished
1. Smoothed/Burnished
2. Unsmoothed/Coarse/Voids
3. Eroded

Appendix B.1 (Conts.): Rim recording sheet for Ile-Ife pottery

Outer Surface Treatment (Slip)

0- None
1- Red/Orange
2- Brown
3- Black Carbon

Outer Surface Treatment (Slip) position

1 Entire Surface
2 Rim
3 Lip
4 Rim and Shoulder

Interior Surface Treatment (Slip) position

0. None
1. Entire interior

Carved Roulette

C1-C25 (See figure 5.4)

Carved Roulette Position

0- None
1- Lip Only
2- Rim Only
3- Rim and Shoulder
4- Rim, Shoulder, and Body
5- Shoulder and Body
6- Body
7- Interior
8- Neck
9- Shoulder

Plastic Motif

0- None
1- Twine Impression
2- Unidentified Twine Impression
3- Unidentified carved Roulette
4- Maize Cob
5- Comb Impression
6- Wavy Dragged Impression
7- Finger nail Impression
8- Thumb Impression

Appendix B.2: Bodysherd single decoration by excavation unit and level

Unit	Level	PL	SP	TW	UT	PA	PC	DC	SG	IN	CR	HG	CH	CRB	CI	PD	GM	UW	CS
IO- B	1	152	2	5				2		2		5						1	
IO- B	2	64	2	7						1		3							
IO- B	3	58		2						1								1	
IO- B	4	950	41	48				5	2	14	2	31		2	3		6	25	
IO- B	5	250	6	23						3	1	10					1	9	
IO- B	6	394	35	20					1	7		6					2		
IO- B	7	326	16	17	4			3		4	3	6		2				3	
IO- B	8	471	14	14				2	1	4	1	7					1	4	
IO - C	1	202	8	12			1	3		1		6		1				12	
IO - C	2	345	6	23	1			1	1	1	2	8					1	30	
IO - C	3	299	20	23						3		2		1			2	3	
IO - C	4	826	28	34			2	3	1	3							7		1
IO - C	5	1547	36	74	1		1	3	4	4	1	33	1	2	1		2		
IO - C	6	898	59	77	3		2	3	5	16	4	26	1	1			6	16	
IO - C	7	409	6	33				1	2	5		14						3	

Note: The sampling fraction is 100%. Plastic motifs: PL (Plain), SP (Slip), TW (Twisted Twine), UT (Unidentified Twisted Twine), PA (Punctate Circular), PA (Punctate Angular), DC (Dragged Comb), SG (Single Groove), IN (Incision), CR (Cross-Hatched), HG (Horizontal Grooves), CH (Channels-s), CRB (Condor/Raised/Bosses), CI (Comb Impression), PD (Perforated), GM (Geometric), UW (Unidentified/Weathered), CS (Circular Stylus)

Appendix B.2 (Cont.): Bodysherd single decoration by excavation unit and level

Unit	Level	PL	SP	TW	UT	PA	PC	DC	SG	IN	CR	HG	CH	CRB	CI	PD	GM	UW	CS
IO - D	1	115		3				1				1						6	
IO - D	2	218	11	9						2		9							
IO - D	3	400	15	15			3	1		1	1	9					1	5	
IO - D	4	471	8	23	1		1	2	1	5	3	16						15	
IO - D	5	502	11	39			2	2		1		9		1			1	4	
IO - D	6	713	51	103			2	1	2	4	1	17					3	4	
IO - D	7	470	40							1	1	13	1				2	7	
OO - A	1	451	11	14			1				3	9		1				12	
OO - A	2	1470	62	59			1	3	3	4	1	31	1	2			1	18	1
OO - A	3	871	2	27			2	1	2	2	1	6	2		1	1	2	10	
OO - A	4	309	8	8								2		1					
OO - A	5	182	2	2				1		1		5						1	
OO - A	6	346	8	1			3							1			3	5	
OO - A	6 ft 1	77	2	7		1						2	2					46	1
OO - A	7	339	16	16			1					3			1		1	13	

Note: The sampling fraction is 100%. Plastic motifs: PL (Plain), SP (Slip), TW (Twisted Twine), UT (Unidentified Twisted Twine), PA (Punctate Circular), PA (Punctate Angular), DC (Dragged Comb), SG (Single Groove), IN (Incision), CR (Cross-Hatched), HG (Horizontal Grooves), CH (Channels-s), CRB (Condor/Raised/Bosses), CI (Comb Impression), PD (Perforated), GM (Geometric), UW (Unidentified/Weathered), CS (Circular Stylus)

Appendix B.2 (Cont.): Bodysherd single decoration by excavation unit and level

Unit	Level	Carved roulette																							
		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24
IO- B	1	4	1														1				3				1
IO- B	2	1	3														1								
IO- B	3	1	1																						
IO- B	4	9	36	2			1				1						3				8				
IO- B	5	4	19														2				1				
IO- B	6	3	17				1										1				6				
IO- B	7	3	5	4			2							1				2			7				
IO- B	8	1	6	2								1									3				1
IO - C	1	5	8																						
IO - C	2	12	13					1						2											
IO - C	3	4	17											1											
IO - C	4	19	21	1				3						1			2								
IO - C	5	32	16	1			1							3			2	1			5				
IO - C	6	13	32				2	5	2								1				6				
IO - C	7	8	20				1										1	1			3				

Note: Only carved roulette categories are presented in this table. Sampling fraction is 100%. For visual representation of each of the carved roulette category see table 5. 6

Appendix B.2 (Cont.): Bodysherd single decoration by excavation and level

Unit	Level	Carved roulette																							
		C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24
IO - D	1		5								1										1				
IO - D	2	6	2								1										4	1			
IO - D	3	6	18	1													1				6		1		
IO - D	4	13	15														4	1			11				
IO - D	5	13	18	2						1							3	1			2	1			
IO - D	6	9	41	3					1		1		1	1	1		5	1			6			1	
IO - D	7	10	24	3									2				1	1			1				
OO - A	1	1	8				2																		1
OO - A	2	21	25	9							2						6	8	1		3				
OO - A	3	3	8	3	1						1						2		1		2				
OO - A	4	4	4																		2				
OO - A	5	1	6															1			1				
OO - A	6	4	10	1																	1		1		
OO - A	6 ft 1	4	1	1																	2				
OO - A	7	2	8	2													1	1			1				

Note: Only carved roulette categories are presented in this table. Sampling fraction is 100%. For visual representation of each of the carved roulette category see table 5. 6

Appendix B.3: Coded bodysherds multiple decoration by excavation unit and level

Unit	Level	HD	PC	CR	ND	NO	MA	SP	SE	SI	CD	PI	PII	PII	PIV	PV
IO-B	1	2	3	4	2	3	3	1	0	0	0	1	13	0	0	0
IO-B	1	3	3	4	1	2	0	1	2	2	0	5	0	0	0	0
IO-B	1	2	1	0	1	2	3	1	0	0	0	16	12	0	0	0
IO-B	3	3	3	4	2	0	1	2	0	0	0	13	4	15	0	
IO-B	4	3	1	3	1	0	3	1	0	0	0	2	15	0	0	0
IO-B	4	3	3	4	2	0	3	1	0	0	0	4	20	0	0	0
IO-B	4	3	1	3	2	0	3	2	0	1	0	5	13	0	0	0
IO-B	4	3	1	0	1	3	1	1	0	0	0	10	13	0	0	0
IO-B	4	2	1	1	1	0	1	1	0	0	0	12	20	0	0	0
IO-B	4	2	2	4	3	2	1	2	0	0	0	13	15	0	0	0
IO-B	4	2	3	4	2	0	3	2	0	0	17	13	0	0	0	0
IO-B	4	2	1	0	2	0	2	1	1	0	0	15	0	0	0	0
IO-B	4	3	3	4	1	0	0	2	0	0	0	20	4	0	0	0
IO-B	4	1	3	4	2	0	2	3	0	0	0	20	10	15	0	0
IO-B	4	2	3	4	1	2	1	2	0	0	0	20	11	0	0	0
IO-B	4	1	4	3	2	0	1	1	0	0	0	20	12	0	0	0
IO-B	5	2	1	1	1	3	1	1	0	0	7	13	0	0	0	0
IO-B	5	3	4	3	1	3	0	1	0	0	0	15	13	0	0	0
IO-B	6	2	1	0	1	0		1	1	0	0	1	12	0	0	0
IO-B	6	2	4	3	1	2	3	1	1	2	0	5	13	0	0	0
IO-B	6	2	1	0	1	3	3	1	0	0	0	13	15	0	0	0
IO-B	6	3	1	0	1	2	2	2	0	0	0	20	15	0	0	0
IO-B	7	3	4	4	2	0	0	1	2	0	0	14	10	0	0	0
IO-B	8	2	2	0	1	2	1	1	0	0	20	12	0	0	0	0
IO-B	8	1	4	2	1	0	2	1	0	0	8	13	0	0	0	0
IO-C	1	3	1	0	1	3	1	1	0	0	0	1	13	0	0	0
IO-C	2	3	3	4	1	2	2	1	0	0	20	12	0	0	0	0
IO-C	2	2	1	1	1	2	2	1	0	0	0	16	13	0	0	0
IO-C	3	3	3	4	1	0	3	1	0	1	0	5	13	0	0	0
IO-C	3	3	4	4	3	2	3	1	0	0	0	15	13	0	0	0
IO-C	3	3	3	4	2	0	2	1	0	0	0	18	13	0	0	0
IO-C	4	3	3	4	2	0	1	3	2	2	0	1	13	0	0	0
IO-C	4	3	3	4	1	0	1	1	1	0	0	2	15	0	0	0
IO-C	4	3	3	4	2	0	3	3	1	1	0	10	0	0	0	0
IO-C	4	3	1	0	3	2	3	1	0	0	0	15	13	0	0	0

Note: Sampling fraction is 100%. For the description of the codes see appendix B.1. Variables: HD (Hardness), PC (Paste color), CR (Core), ND (Non Plastic Inclusion-Dominant), NO (Non Plastic Inclusion-Others), MA (Mica), SP (Surface Preparation), SE (Slip-Exterior), SI (Slip-Interior), CD (Carved), PI, (Plastic I), PI (Plastic II), PIII (Plastic III), PIV (Plastic IV), PV (Plastic V).

Appendix B.3 (Cont.): Coded bodysherds multiple decoration by excavation unit and level

Unit	Level	HD	PC	CR	ND	NO	MA	SP	SE	SI	CD	PI	PII	PII	PIV	PV
IO-C	4	3	3	4	1	0	2	1	0	0	0	15	13	0	0	0
IO-C	4	2	1	3	1	0	1	1	0	0	0	20	15	0	0	0
IO-C	5	3	3	4	3	2	0	1	0	0	0	8	15	0	0	0
IO-C	5	3	4	2	2	0	3	1	1	1	0	11	0	0	0	0
IO-C	5	3	1	3	2	3	2	2	0	0	20	12	0	0	0	0
IO-C	5	3	3	4	1	0	0	1	0	1	0	15	13	0	0	0
IO-C	5	3	3	4	2	0	2	2	0	0	0	15	20	0	0	0
IO-C	5	3	1	3	2	0	3	1	0	0	0	20	13	0	0	0
IO-C	5	2	1	0	2	0	1	1	0	0	0	20	15	0	0	0
IO-C	6	2	1	0	1	3	3	1	0	0	0	2	12	0	0	0
IO-C	6	3	3	4	2	1	3	1	0	0	0	11	14	0	0	0
IO-C	6	3	3	4	1	3	3	1	0	0	21	12	0	0	0	0
IO-C	6	3	1	2	1	0	2	1	0	0	0	15	13	0	0	0
IO-C	6	2	1	3	1	3	3	1	0	0	0	20	15	0	0	0
IO-D	1	2	1	2	1	0	1	1	0	0	0	12	20	0	0	0
IO-D	2	3	3	4	1	0	1	1	2	2	0	13	6	15	20	0
IO-D	2	3	4	3	3	2	0	1	1	0	0	15	0	0	0	0
IO-D	3	3	4	4	1	3	0	1	0	0	0	11	14	0	0	0
IO-D	3	1	1	1	2	0	3	3	0	0	0	11	20	0	0	0
IO-D	3	3	4	1	1	3	3	1	1	1	0	16	12	0	0	0
IO-D	3	3	3	4	1	0	2	3	0	0	0	20	12	0	0	0
IO-D	4	1	3	4	3	2	1	1	0	0	0	13	20	15	0	0
IO-D	4	3	1	0	3	2	2	1	1	1	0	13	0	0	0	0
IO-D	5	2	1	0	2	1	2	1	0	0	6	12	0	0	0	0
IO-D	5	2	1	3	2	0	0	1	0	1	0	13	17	0	0	0
IO-D	5	2	3	5	1	0	2	1	1	1	0	13	9	0	0	0
IO-D	5	3	1	0	1	3	3	1	0	0	19	13	0	0	0	0
IO-D	5	1	1	0	2	0	3	1	1	1	0	20	0	0	0	0
IO-D	6	1	3	4	1	2	1	1	0	0	0	1	20	0	0	0
IO-D	6	2	1	2	1	3	2	1	0	0	0	2	13	0	0	0
IO-D	6	3	3	4	2	0	3	1	0	0	0	6	14	0	0	0
IO-D	6	3	3	4	1	3	0	1	0	0	0	9	13	0	0	0
IO-D	6	2	3	4	1	0	1	1	0	0	0	11	20	0	0	0
IO-D	6	1	1	0	1	2	1	1	0	0	0	12	15	0	0	0
IO-D	6	3	1	0	1	2	1	2	0	0	0	13	6	0	0	0
IO-D	6	2	1	3	1	3	3	1	0	0	0	13	15	0	0	0
IO-D	6	3	3	4	2	0	1	2	0	0	0	13	20	0	0	0

Note: Sampling fraction is 100%. For the description of the codes see appendix B.1. Variables: HD (Hardness), PC (Paste color), CR (Core), ND (Non Plastic Inclusion-Dominant), NO (Non Plastic Inclusion-Others), MA (Mica), SP (Surface Preparation), SE (Slip-Exterior), SI (Slip-Interior), CD (Carved), PI, (Plastic I), PI (Plastic II), PIII (Plastic III), PIV (Plastic IV), PV (Plastic V).

Appendix B.3 (Cont.): Coded bodysherds multiple decoration by excavation unit and level

Unit	Level	HD	PC	CR	ND	NO	MA	SP	SE	SI	CD	PI	PII	PII	PIV	PV
IO-D	6	3	3	4	2	3	1	1	0	0	16	13	0	0	0	0
IO-D	6	3	1	0	1	2	3	1	0	1	16	13	0	0	0	0
IO-D	6	3	1	0	1	2	1	1	0	0	17	13	0	0	0	0
IO-D	6	3	3	4	0	0	3	1	0	0	0	14	15	0	0	0
IO-D	6	2	1	1	2	0	3	1	0	0	0	15	13	0	0	0
IO-D	6	3	2	2	1	3	1	1	0	0	0	16	12	1	0	0
IO-D	6	3	2	3	1	0	1	1	2	2	22	18	0	0	0	0
IO-D	6	3	3	4	2	0	2	1	0	0	0	20	9	0	0	0
IO-D	6	2	3	4	2	0	1	1	0	0	0	20	15	0	0	0
IO-D	7	3	1	0	1	3	1	1	0	0	0	1	20	7	0	0
IO-D	7	3	1	0	1	3	2	1	0	0	0	2	18	0	0	0
IO-D	7	3	1	0	1	0	0	1	0	0	0	5	15	0	0	0
IO-D	7	2	3	4	1	3	1	1	0	0	0	10	13	0	0	0
IO-D	7	2	1	2	2	3	3	1	0	0	0	17	2	0	0	0
IO-D	7	2	1	0	1	2	2	1	0	0	0	20	4	0	0	0
IO-D	7	3	3	4	2	0	2	1	0	0	0	20	9	0	0	0
OOA	1	3	3	4	2	0	0	2	0	0	0	12	15	0	0	0
OOA	1	2	1	3	1	3	1	1	0	0	0	13	3	0	0	0
OOA	1	3	3	4	2	0	0	1	0	0	0	20	15	0	0	0
OOA	2	3	2	3	1	2	2	2	0	0	0	1	13	0	0	0
OOA	2	3	3	4	1	2	1	1	0	0	0	13	15	0	0	0
OOA	2	1	4	1	2	0	0	3	0	0	0	14	4	0	0	0
OOA	2	2	2	2	1	0	0	1	0	0	0	18	15	12	0	0
OOA	2	3	1	0	2	0	1	1	0	0	0	20	11	0	0	0
OOA	3	2	3	4	2	0	1	2	0	0	0	1	15	0	0	0
OOA	4	2	2	4	2	0	2	2	0	0	0	11	14	0	0	0
OOA	4	1	3	4	2	3	1	2	0	0	0	20	15	0	0	0
OOA	5	1	2	3	1	2	1	1	0	2	0	1	0	0	0	0
OOA	5	3	1	0	1	2	1	2	0	0	0	1	6	20	0	0
OOA	6	1	2	3	1	0	1	1	0	0	0	20	11	0	0	0
OOA	6Ft1	2	1	0	1	2	1	1	0	0	0	1	12	0	0	0
OOA	6Ft1	1	1	0	1	2	1	1	0	0	0	12	20	0	0	0
OOA	6Ft1	1	1	0	1	0	1	2	0	0	20	12	0	0	0	0
OOA	6Ft1	3	1	0	2	0	1	2	0	0	0	13	6	0	0	0
OOA	6Ft1	2	3	4	1	2	1	2	0	0	0	20	1	0	0	0
OOA	6Ft1	2	1	3	1	3	1	2	0	0	0	20	15	0	0	0

Note: Sampling fraction is 100%. For the description of the codes see appendix B.1. Variables: HD (Hardness), PC (Paste color), CR (Core), ND (Non Plastic Inclusion-Dominant), NO (Non Plastic Inclusion-Others), MA (Mica), SP (Surface Preparation), SE (Slip-Exterior), SI (Slip-Interior), CD (Carved), PI, (Plastic I), PI (Plastic II), PIII (Plastic III), PIV (Plastic IV), PV (Plastic V).

Appendix B.4: Coded rimsherds (≥ 3cm across) data by excavation unit and level

Unit	Level	DM	R%	TK	AG	VP	TY	LP	HD	PC	CR	ND	NO	MA	SP	SL	SP	IST	CD	CDP	PI	PIP	PII	PIIP
IO-B	1	16	7	8.3	3	1	101	1	3	1	0	1	0	0	1	1	1	1	0	0	0	0	0	0
IO-B	1	25	6	11	5	1	503	1	3	2	4	1	0	1	1	1	1	1	0	0	0	0	0	0
IO-B	1	21	5	11.54	5	1	604	1	3	1	0	1	0	1	1	2	1	2	0	0	0	0	0	0
IO-B	1			17.37	2	1	801	1	3	2		0	1	3	1	0	0	0	0	0	0	0	0	0
IO-B	1	31	6	20.14	2	1	802	1	3	1	0	1	0	1	1	0	0	0	0	0	0	0	0	0
IO-B	1	17	6	8.25	5	1	604	1	3	3	4	1	0	1	3	0	0	0	0	0	0	0	0	0
IO-B	2	20	7	8.64	5	1	602	1	3	2	4	1	0	2	1	0	0	1	0	0	0	0	0	0
IO-B	2	18	4.5	8.97	2	2	101	1	2	2	3	3	1	1	2	0	0	0	0	0	20	9	0	0
IO-B	3	22	8	12.31	4	1	502	1	1	1	0	3	1		1	1	1	1	0	0	0	0	0	0
IO-B	3	23	10	16.94	5	1	609	1	3	1	0	1	3	2	1	1	1	1	0	0	13	7	0	0
IO-B	4	25	9	24.54	4	2	902	1	3	1	2	1	3	1	2	0	0	0	0	0	12	8	0	0
IO-B	4	24	9	12.56	5	2	803	1	1	2	0	3	1	1	3	0	0	0	0	0	0	0	0	0
IO-B	4			8.4	5	1	601	1	3	1	0	1	0	1	1	0	0	0	0	0	0	0	0	0
IO-B	4	30	10	36.25	2	1	803	1	2	3	4	1	3	1	2	1	1	0	0	0	0	0	0	0
IO-B	4	28	9	35.93	2	1	803	1	3	1	0	3	1	1	0	0	0	0	0	0	0	0	0	0
IO-B	4	23	10	15.56	5	1	703	1	2	1	1	3	1	1	1	0	0	0	0	0	0	0	0	0
IO-B	4	15	10	8.55	4	2	301	1	2	1	0	3	1	1	1	1	1	1	0	0	1	6	0	0
IO-B	4	18	7	6.33	2	3	404	1	2	3	4	3	1	1	2	0	0	0	0	0	1	6	4	9
IO-B	4	23	5	8.36	2	2	101	1	3	1	0	1	3	1	1	0	0	0	0	0	4	5	0	0
IO-B	5	20	8	8.79	2	2	302	1	1	3	4	2	0	1	1	0	0	0	0	0	4	9	0	0
IO-B	5	27	8	29.04	2	1	804	1	3	1	0	3	1	1	2	0	0	0	0	0	0	0	0	0
IO-B	5	25	8	15.39	5	2	606	1	2	1	3	1	2	1	1	0	0	0	0	0	1	5	4	9

Note: See appendix B.1 for code description. Sampling Fraction 100%. Variables: DM (Diameter), R% (Rim Percentage), TK (Thickness), AG (Angle), VP (Vessel Parts Represented), TY (Type), LS (Lip Shape), SL (Slip), SP (Slip Position), IST (Interior Surface Treatment), HD (Hardness), PC (Paste color), CR (Core), ND (Non Plastic Inclusion-Dominant), NO (Non Plastic Inclusion-Others), MA (Mica), SP (Surface Preparation), CD (Carved), CDP (Carved Position), PI, (Plastic I), PIP (Plastic I Position), PII (Plastic II), PIIP (Plastic II Position).

Appendix B.4 (Cont.): Coded rimsherds (≥ 3cm across) data by excavation unit and level

Unit	Level	DM	R%	TK	AG	VP	TY	LP	HD	PC	CR	ND	NO	MA	SP	SL	SP	IST	CD	CDP	PI	PIP	PII	PIIP
IO-B	5	16	5	8.23	2	2	101	1	2	3	4	2	1	1	1	0	0	0	0	0	0	0	0	0
IO-B	6	24	6	8.5	4	2	101	1	3	1	2	1	3	2	1	1	2	0	0	0	6	5	0	0
IO-B	6	22	6	6.47	2	3	101	1	2	3	4	2	0	1	1	1	2	1	0	0	14/1/15	3	20	9
IO-B	6	22	5	11.6	2	3	101	1	3	3	4	2	0	1	3	0	0	0	0	0	1	5	20	9
IO-B	8	42	6	8.3	4	3	301	1	2	1	3	3	1	3	2	0	0	1	8	6	15	9	0	0
IO-B	8	15	11	6.41	2	3	402	1	2	3	4	2	3	2	3	0	0	0	0	0	15	9	0	0
IO-B	8	19	10	10.89	4	2	501	1	3	3	4	1	2	1	2	0	0	0	0	0	0	0	0	0
IO-B	8	17	10	11.88	5	1	702	1	3	1	0	2	3	1	3	0	0	0	0	0	0	0	0	0
IO-B	8	24	5	7.51	2	3	301	1	2	3	4	1	0	1	2	1	2	0	1	6	4	9	0	0
IO-B	8	14	9	6.63	3	3	301	1	3	3	4	2	0	1	1	0	0	0	0	0	15	9	0	0
IO-B	8	28	5	9.81	2	3	302	1	1	1	1	2	1	1	3	0	0	0	0	0	13	3	15	9
IO-B	8	0	0	16.34	5	1	501	1	3	4	4	2	0	1	3	0	0	0	0	0	0	0	0	0
IO-B	8	19	9	9.84	5	1	601	1	3	1	3	1	2	1	1	0	0	0	0	0	0	0	0	0
IO-B	8	14	10	11.26	5	1	604	1	3	4	4	3	2	1	1	0	0	0	0	0	0	0	0	0
IO-B	8	0	0	20.78	4	1	802	1	2	2	0	1	2	1	3	0	0	0	0	0	0	0	0	0
IO-B	8	0	0	8.56	4	1	501	1	2	4	4	1	3	2	3	0	0	0	0	0	0	0	0	0
IO-B	8	0	0	8.16	2	3	401	1	2	1	0	1	2	2	1	0	0	0	0	0	0	0	0	0
IO-B	2	23	7	11.82	3	2	M1	1	3	2	2	2	0	2	2	0	0	1	0	0	2	6	6	1
IO-B	1	16	10	12.84	3	2	M1	1	3	3	4	2	1	3	2	0	0	0	0	0	11	1	0	0
IO-B	1	42	5	13.21	2	2	103	2	2	1	4	3	1	3	1	1	3	1	0	0	1	5	0	0
IO-B	5	22	10	8.97	5	1	607	4	2	4	3	3	2	1	2	0	0	0	0	0	0	0	0	0
IO-B	1			9.57	5	1	706	5	2	1	3	1	3	1	1	0	0	0	0	0	0	0	0	0
IO-B	2	20	6	11.07	5	1	608	5	2	3	5	1	3	1	2	0	0	0	0	0	0	0	0	0

Note: See appendix B.1 for code description. Sampling Fraction 100%. Variables: DM (Diameter), R% (Rim Percentage), TK (Thickness), AG (Angle), VP (Vessel Parts Represented), TY (Type), LS (Lip Shape), SL (Slip), SP (Slip Position), IST (Interior Surface Treatment), HD (Hardness), PC (Paste color), CR (Core), ND (Non Plastic Inclusion-Dominant), NO (Non Plastic Inclusion-Others), MA (Mica), SP (Surface Preparation), CD (Carved), CDP (Carved Position), PI, (Plastic I), PIP (Plastic I Position), PII (Plastic II), PIIP (Plastic II Position).

Appendix B.4 (Cont.): Coded rimsherds data (≥ 3cm across) by excavation unit and level

Unit	Level	DM	R%	TK	AG	VP	TY	LP	HD	PC	CR	ND	NO	MA	SP	SL	SP	IST	CD	CDP	PI	PIP	PII	PIIP
IO-B	2	23	5	13.17	5	1	505	5	3	3	4	1	0	3	3	0	0	0	0	0	0	0	0	0
IO-B	5			12.73	5	1	705	5	3	1	0	1	2	0	1	0	0	0	0	0	0	0	0	0
IO-B	5	18	10	11.39	5	1	702	6	3	1	3	1	2	1	1	0	0	0	0	0	0	0	0	0
IO-B	5	18	6	8.78	5	1	602	6	3	3	4	2	0	1	1	0	0	0	0	0	0	0	0	0
IO-B	6	10	12	7.7	5	1	601	6	2	1	0	3	2	1	1	0	0	0	0	0	0	0	0	0
IO-C	1	26	6	7.75	4	2	502	1	2	1	0	2	0	3	1	1	1	1	0	0	12	8	0	0
IO-C	2	0	0	10	2	3	101	1	2	2	3	1	3	3	1	0	0	0	0	0	0	0	0	0
IO-C	3	16	6	8.56	4	2	101	1	2	2	2	1	3	2	1	0	0	0	0	0	0	0	0	0
IO-C	4	28	6	8.83	5	1	607	1	2	1	0	2	0	1	3	0	0	0	0	0	0	0	0	0
IO-C	4	14	10	5.73	4	3	102	1	2	1	3	2	0	2	1	2	1	2	0	0	0	0	0	0
IO-C	4	11	9	7.41	4	3	101	1	2	3	4	2	0	1	0	0	0	0	0	0	0	0	0	0
IO-C	5	18	9	8.8	4	2	101	1	2	3	4	1	3	0	1	0	0	1	0	0	15	9	20	9
IO-C	5	17	10	9.51	4	1	101	1	3	3	4	1	3	1	1	0	0	1	0	0	15	3	0	0
IO-C	5	22	7	12.02	5	1	901	1	2	1	0	1	3	2	1	0	0	0	0	0	11	1	0	0
IO-C	5	24	5	8.68	5	1	702	1	2	2	2	2	0	3	1	0	0	1	0	0	0	0	0	0
IO-C	5	15	10	8.37	5	1	703	1	1	1	0	2	0	3	1	0	0	0	0	0	0	0	0	0
IO-C	5	0	0	7.72	2	3	401	1	2	3	4	2	0	1	1	3	0	0	0	0	15	10	0	0
IO-C	5	0	0	7.11	4	2	101	1	3	2	0	1	3	1	1	0	0	0	0	0	14	3	0	0
IO-C	6	14	8	8.26	2	2	101	1	2	1	0	3	1	1	1	0	0	0	0	0	11	9	0	0
IO-C	6	17	7	8.11	4	2	502	1	1	3	4	1	3	1	1	1	1	1	0	0	13	8	0	0
IO-C	6	13	8	7.53	5	3	201	1	1	4	4	1	3	2	1	0	0	0	0	0	0	0	0	0
IO-C	6	0	0	606	2	3	401	1	2	3	4	1	2	1	1	0	0	0	0	0	14	2	0	0
IO-C	6	0	0	6.15	2	3	401	1	2	3	4	2	0	3	1	0	0	0	0	0	2	6	10	9

Note: See appendix B.1 for code description. Sampling Fraction 100%. Variables: DM (Diameter), R% (Rim Percentage), TK (Thickness), AG (Angle), VP (Vessel Parts Represented), TY (Type), LS (Lip Shape), SL (Slip), SP (Slip Position), IST (Interior Surface Treatment), HD (Hardness), PC (Paste color), CR (Core), ND (Non Plastic Inclusion-Dominant), NO (Non Plastic Inclusion-Others), MA (Mica), SP (Surface Preparation), CD (Carved), CDP (Carved Position), PI, (Plastic I), PIP (Plastic I Position), PII (Plastic II), PIIP (Plastic II Position).

Appendix B.4 (Cont.): Coded rimsherds (≥ 3cm across) data by excavation unit and level

Unit	Level	DM	R%	TK	AG	VP	TY	LP	HD	PC	CR	ND	NO	MA	SP	SL	SP	IST	CD	CDP	PI	PIP	PII	PIIP
IO-C	6	14	10	7.39	4	3	101	1	2	3	4	1	0	2	1	0	0	0	0	0	1	6	14	2
IO-C	6	0	0	5.68	2	3	401	1	3	3	4	2	0	2	1	0	0	1	0	0	0	0	0	0
IO-C	6	0	0	5.48	4	3	101	1	3	1	0	2	1	1	1	0	0	0	0	0	0	0	0	0
IO-C	6	0	0	14.33	4	2	103	1	3	1	0	2	1	3	1	1	1	1	0	0	0	0	0	0
IO-C	7	15	10	9.39	5	3	101	1	3	1	3	2	0	0	1	1	1	1	0	0	0	0	0	0
IO-C	7	17	8	11.11	2	2	202	1	1	3	4	2	0	1	3	0	0	0	0	0	15	6	12	6
IO-C	7	18	8	10.97	5	1	702	1	3	3	4	1	2	3	1	0	0	0	0	0	0	0	0	0
IO-C	6	0	0	8.69	5	1	601	1	3	3	4	1	0	3	1	1	1	1	0	0	0	0	0	0
IO-C	5	0	0	7.88	3	2	101	1	2	1	4	2	1	3	1	1	1	1	0	0	0	0	0	0
IO-C	2	20	14	8.57	5	2	503	1	3	3	4	1	3	0	1	1	2	1	0	0	13	9	0	
IO-C	6	30	8	12.06	4	3	103	2	3	3	5	3	1	2	1	0	0	1	0	0	13	6	0	0
IO-C	4	0	0	11.82	5	2	607	3	2	3	4	1	2	1	1	0	0	0	0	0	0	0	0	0
IO-C	5	21	8	7.89	5	1	702	3	3	1	0	1	3	0	1	0	0	1	0	0	0	0	0	0
IO-C	5	0	0	8.89	5	1	706	3	1	4	4	2	3	3	1	0	0	0	0	0	0	0	0	0
IO-C	6	18	7	7.19	3	1	102	3	2	3	4	1	3	3	1	0	0	0	0	0	0	0	0	0
IO-C	2	0	0	8.08	3	2	104	3	2	2	2	2	0	3	1	0	0	0	0	0	0	0	0	0
IO-C	4	0	0	8.37	3	2	104	3	2	1	0	2	0	2	1	1	1	1	0	0	0	0	0	0
IO-C	5	30	7	9.03	5	1	705	4	3	1	0	1	2	2	1	0	0	0	0	0	12	2	0	0
IO-C	6	24	8	13.05	2	1	202	4	2	1	0	2	0	1	1	0	0	0	0	0	14	9	0	0
IO-C	4	25	5	10	5	1	705	5	2	1	0	1	2	3	3	0	0	0	0	0	0	0	0	0
IO-C	2	0	0	9.17	5	2	601	6	2	3	4	2	0	1	3	0	0	0	20	9	11	8	0	0
IO-C	4	0	0	7.41	4	3	101	6	3	1	2	1	2	0	1	1	2	1	0	0	6	9	13	6
IO-D	1	0	0	13.68	5	2	504	1	2	2	0	1	3	1	3	1	3	0	0	0	5	9	0	0

Note: See appendix B.1 for code description. Sampling Fraction 100%. Variables: DM (Diameter), R% (Rim Percentage), TK (Thickness), AG (Angle), VP (Vessel Parts Represented), TY (Type), LS (Lip Shape), SL (Slip), SP (Slip Position), IST (Interior Surface Treatment), HD (Hardness), PC (Paste color), CR (Core), ND (Non Plastic Inclusion-Dominant), NO (Non Plastic Inclusion-Others), MA (Mica), SP (Surface Preparation), CD (Carved), CDP (Carved Position), PI, (Plastic I), PIP (Plastic I Position), PII (Plastic II), PIIP (Plastic II Position).

Appendix B.4 (Cont.): Coded rimsherds data (≥ 3cm across) by excavation unit and level

Unit	Level	DM	R%	TK	AG	VP	TY	LP	HD	PC	CR	ND	NO	MA	SP	SL	SP	IST	CD	CDP	PI	PIP	PII	PIIP
IO-D	2	24	14	10.67	5	2	603	1	3	3	4	2	0	0	1	0	0	0	0	0	0	0	0	0
IO-D	2	25	10	10.22	5	2	603	1	3	3	4	2	0	1	1	0	0	0	0	0	0	0	0	0
IO-D	2	0	0	12.28	5	1	502	1	3	1	0	1	3	1	1	1	1	1	0	0	0	0	0	0
IO-D	2	20	10	15.8	6	1	803	1	3	1	0	2	3	2	3	0	0	0	0	0	0	0	0	0
IO-D	2	0	0	8.62	5	4	706	1	2	1	0	1	3	1	2	0	0	1	0	0	15	8	14	8
IO-D	2	0	0	12.81	4	3	101	1	2	2	0	1	3	0	1	1	0	1	0	0	14	2	5	2
IO-D	3	0	0	8.8	5	1	601	1	2	2	3	1	3	1	1	1	1	1	0	0	0	0	0	0
IO-D	3	0	0	14.79	5	1	504	1	1	3	4	1	0	3	1	2	1	2	0	0	0	0	0	0
IO-D	3	0	0	9.96	5	1	701	1	3	1	0	1	3	2	1	1	1	1	0	0	0	0	0	0
IO-D	3	17	7	6.29	2	3	402	1	2	3	4	2	0	1	1	2	1	2	0	0	2	6	20	9
IO-D	4	0	0	6.13	2	3	403	1	2	3	4	1	2	2	1	2	1	1	0	0	4	9	0	0
IO-D	4	20	7	7.75	5	1	602	1	2	3	4	2	1	0	1	0	0	1	0	0	0	0	0	0
IO-D	4	0	0	8.39	4	1	503	1	2	2	3	1	0	2	1	0	0	0	0	0	0	0	0	0
IO-D	5	0	0	5.6	2	3	402	1	2	1	3	1	3	2	1	1	1	1	0	0	1	6	20	10
IO-D	5	0	0	7.49	2	3	302	1	2	2	0	1	2	1	1	0	0	0	0	0	15	9	0	0
IO-D	5	20	5	15.84	5	1	604	1	1	2	4	2	1	2	3	1	1	1	0	0	5	2	0	0
IO-D	5	0	0	10.24	5	2	702	1	2	3	4	2	1	3	1	0	0	0	0	0	9	9	0	0
IO-D	5	21	6	6.09	5	1	604	1	1	1	0	1	2	2	1	1	1	1	0	0	0	0	0	0
IO-D	6	0	0	12.87	2	3	404	1	3	3	4	2	0	3	2	0	0	0	0	0	1	6	15	2
IO-D	6	12	10	5.16	3	2	503	1	2	2	4	1	2	1	1	0	0	0	0	0	11	9	0	0
IO-D	6	0	0	10.62	3	2	203	1	2	1	4	1	3	2	2	0	0	1	0	0	5	5	0	0
IO-D	6	15	9	9.18	5	1	601	1	2	1	0	1	2	2	1	0	0	0	0	0	0	0	0	0
IO-D	6	16	11	8.38	2	3	404	1	2	3	4	1	0	1	1	0	0	0	0	0	2	6	15	9

Note: See appendix B.1 for code description. Sampling Fraction 100%. Variables: DM (Diameter), R% (Rim Percentage), TK (Thickness), AG (Angle), VP (Vessel Parts Represented), TY (Type), LS (Lip Shape), SL (Slip), SP (Slip Position), IST (Interior Surface Treatment), HD (Hardness), PC (Paste color), CR (Core), ND (Non Plastic Inclusion-Dominant), NO (Non Plastic Inclusion-Others), MA (Mica), SP (Surface Preparation), CD (Carved), CDP (Carved Position), PI, (Plastic I), PIP (Plastic I Position), PII (Plastic II), PIIP (Plastic II Position).

Appendix B.4 (Cont.): Coded rimsherds data (≥ 3cm across) by excavation unit and level

Unit	Level	DM	R%	TK	AG	VP	TY	LP	HD	PC	CR	ND	NO	MA	SP	SL	SP	IST	CD	CDP	PI	PIP	PII	PIIP
IO-D	6	17	8	8.55	5	1	601	1	3	1	3	1	2	1	1	0	0	0	0	0	0	0	0	0
IO-D	6	0	0	7.53	2	3	401	1	2	3	4	1	3	1	1	0	0	0	0	0	1	6	0	0
IO-D	7	19	13	7.21	2	3	302	1	2	3	4	1	0	2	1	0	0	1	0	0	18	9	0	0
IO-D	7	15	8	9.98	2	2	401	1	2	1	3	1	0	1	1	1	2	1	0	0	5	9	0	0
IO-D	7	24	4	8.76	2	3	401	1	2	3	4	1	2	2	1	0	0	0	3	6	0	0	0	0
IO-D	7	21	14	13.42	5	1	701	1	2	1	4	1	3	1	2	0	0	0	0	0	0	0	0	0
IO-D	7	22	8	12.36	5	1	603	1	2	2	4	2	3	1	1	0	0	0	0	0	0	0	0	0
IO-D	7	0	0	15.33	5	1	603	1	2	1	3	1	3	1	3	0	0	0	0	0	0	0	0	0
IO-D	7	24	9	12.46	3	3	204	2	2	1	3	1	0	0	1	1	1	0	0	0	13	6	0	0
IO-D	4	16	10	11.25	5	2	606	3	3	4	3	1	0	1	1	0	0	0	0	0	13	9	0	0
IO-D	7	21	11	10.49	5	1	607	3	3	1	3	1	2	2	3	0	0	0	0	0	0	0	0	0
IO-D	2	0	0	9.49	4	1	703	3	3	1	0	1	3	3	1	0	0	0	0	0	0	0	0	0
IO-D	2	21	7	14.96	5	2	606	5	2	1	3	1	3	1	1	0	0	0	0	0	13	5	0	0
IO-D	4	25	5	13.29	3	3	204	5	2	1	3	1	3	3	1	1	1	1	0	0	13	6	0	0
IO-D	5	0	0	13.15	5	1	705	5	2	2	0	1	2	1	1	0	0	0	0	0	0	0	0	0
IO-D	2	0	0	8.02	5	2	501	6	2	4	3	2	0	3	1	0	0	1	0	0	13	5	6	5
IO-D	5	0	0	6.76	5	1	602	6	2	3	4	1	0	0	1	0	0	0	0	0	0	0	0	0
OOA	1	19	8	9.5	5	1	701	1	2	1	1	1	3	1	1	0	0	0	0	0	0	0	0	0
OOA	1	15	14	9.66	5	1	604	1	1	3	4	2	1	1	1	0	0	0	0	0	0	0	0	0
OOA	1	0	0	7.86	5	1	601	1	3	1	0	1	3	3	1	1	1	1	0	0	0	0	0	0
OOA	1	0	0	8.65	5	1	604	1	3	4	3	1	3	3	1	0	0	0	0	0	0	0	0	0
OOA	2	23	11	9.05	5	1	706	1	3	4	1	2	3	2	1	1	0	0	0	0	0	0	0	0
OOA	2	19	8	9.75	3	3	101	1	3	2	1	1	2	0	1	1	2	1	0	0	13	4	0	0

Note: See appendix B.1 for code description. Sampling Fraction 100%. Variables: DM (Diameter), R% (Rim Percentage), TK (Thickness), AG (Angle), VP (Vessel Parts Represented), TY (Type), LS (Lip Shape), SL (Slip), SP (Slip Position), IST (Interior Surface Treatment), HD (Hardness), PC (Paste color), CR (Core), ND (Non Plastic Inclusion-Dominant), NO (Non Plastic Inclusion-Others), MA (Mica), SP (Surface Preparation), CD (Carved), CDP (Carved Position), PI, (Plastic I), PIP (Plastic I Position), PII (Plastic II), PIIP (Plastic II Position).

Appendix B.4 (Cont.): Coded rimsherds data (≥ 3cm across) by excavation unit and level

Unit	Level	DM	R%	TK	AG	VP	TY	LP	HD	PC	CR	ND	NO	MA	SP	SL	SP	IST	CD	CDP	PI	PIP	PII	PIIP
OOA	2	19	5	8.7	5	1	603	1	1	1	0	2	0	3	1	1	1	1	0	0	0	0	0	0
OOA	2	0	0	10.86	5	2	503	1	1	4	4	1	3	3	1	0	0	1	0	0	6	9	10	9
OOA	2	22	10	10.79	4	2	103	1	2	1	0	2	0	2	1	0	0	2	0	0	1	6	12	2
OOA	2	26	7	10.99	5	1	602	1	3	2	0	1	0	1	1	0	0	2	0	0	0	0	0	0
OOA	2	19	9	11.62	5	1	501	1	3	1	0	1	3	1	1	0	0	0	0	0	0	0	0	0
OOA	2	0	0	9.02	2	2	101	1	1	3	2	1	0	1	1	0	0	2	0	0	1	6	0	0
OOA	2	0	0	9.97	5	1	706	1	3	2	0	1	2	2	1	0	0	0	0	0	0	0	0	0
OOA	2	15	6	7.01	1	1	101	1	2	1	0	1	2	2	1	0	0	0	0	0	0	0	0	0
OOA	3	25	9	12.22	3	1	101	1	3	3	4	2	0	1	2	0	0	0	0	0	8	2	0	0
OOA	3	16	15	9.92	5	1	602	1	1	4	4	1	3	1	1	1	1	1	0	0	0	0	0	0
OOA	3	14	10	6.61	3	1	101	1	1	1	3	1	3	3	3	1	1	1	0	0	0	0	0	0
OOA	3	17	6	7.29	2	2	102	1	1	4	4	2	0	3	2	0	0	0	0	0	5	9	0	0
OOA	3	0	0	16.66	2	1	403	1	2	3	4	1	3	3	2	1	1	1	0	0	0	0	0	0
OOA	3	14	9	10.06	5	1	605	5	1	1	0	1	0	3	1	0	0	0	0	0	0	0	0	0
OOA	3	0	0	20.39	3	1	801	2	3	1	0	1	3	3	1	1	10	1	0	0	1	6	0	0
OOA	4	0	0	9.56	4	2	102	1	2	2	4	1	2	3	3	0	0	0	0	0	0	0	0	0
OOA	4	0	0	7.72	4	1	101	1	1	1	3	2	0	3	1	1	1	1	0	0	0	0	0	0
OOA	4	12	10	7.95	5	1	501	1	3	3	4	1	3	2	1	1	1	1	0	0	0	0	0	0
OOA	4	0	0	7.47	5	1	604	1	3	1	3	1	3	2	1	1	1	1	0	0	0	0	0	0
OOA	4	0	0	7.9	5	1	604	1	3	1	3	1	3	3	2	0	0	0	0	0	0	0	0	0
OOA	5	16	7	8.54	5	1	502	1	1	1	3	1	2	1	3	0	0	0	0	0	0	0	0	0
OOA	5	0	0	7.99	5	1	601	1	3	1	0	1	0	3	1	1	1	1	0	0	0	0	0	0

Note: See appendix B.1 for code description. Sampling Fraction 100%. Variables: DM (Diameter), R% (Rim Percentage), TK (Thickness), AG (Angle), VP (Vessel Parts Represented), TY (Type), LS (Lip Shape), SL (Slip), SP (Slip Position), IST (Interior Surface Treatment), HD (Hardness), PC (Paste color), CR (Core), ND (Non Plastic Inclusion-Dominant), NO (Non Plastic Inclusion-Others), MA (Mica), SP (Surface Preparation), CD (Carved), CDP (Carved Position), PI, (Plastic I), PIP (Plastic I Position), PII (Plastic II), PIIP (Plastic II Position).

Appendix B.4 (Cont.): Coded rimsherds data (≥ 3cm across) by excavation unit and level

Unit	Level	DM	R%	TK	AG	VP	TY	LP	HD	PC	CR	ND	NO	MA	SP	SL	SP	IST	CD	CDP	PI	PIP	PII	PIIP
OOA	6	15	14	7.48	5	1	602	1	3	1	0	1	2	2	1	0	0	0	0	0	0	0	0	0
OOA	6	0	0	7.35	3	2	101	1	3	1	4	1	3	1	3	0	0	0	0	0	0	0	0	0
OOA	6	19	7	8.21	5	1	602	1	2	3	4	1	0	1	1	0	0	0	0	0	0	0	0	0
OOA	7	16	10	7.52	5	1	604	1	3	3	4	2	0	3	1	0	0	0	0	0	0	0	0	0
OOA	7	0	0	9.3	5	1	602	1	1	3	4	2	0	3	1	0	0	0	0	0	0	0	0	0
OOA	6 feat.1	7	100	9.17	5	2	501	1	2	1	1	3	1	2	1	1	1	1	0	0	0	0	0	0
OOA	6 feat.1	18	13	8.12	5	1	706	1	2	3	4	2	1	1	1	0	0	0	0	0	0	0	0	0
OOA	6 feat.1	0	0	9.63	5	1	702	1	2	1	0	1	3	2	3	0	0	0	0	0	0	0	0	0
OOA	6 feat.1	12	12	8.54	4	1	701	1	3	1	3	1	3	3	1	0	0	0	0	0	0	0	0	0
OOA	6 feat.1	0	0	7.89	5	1	702	1	3	1	0	2	1	3	1	0	0	0	0	0	0	0	0	0
OOA	6 feat.1	9	10	7.38	5	1	604	1	1	3	4	1	3	3	3	0	0	0	0	0	0	0	0	0
OOA	6 feat.1	0	0	9.21	4	1	701	3	2	3	4	2	0	3	2	3	1	0	0	0	0	0	0	0

Note: See appendix B.1 for code description. Sampling Fraction 100%. Variables: DM (Diameter), R% (Rim Percentage), TK (Thickness), AG (Angle), VP (Vessel Parts Represented), TY (Type), LS (Lip Shape), SL (Slip), SP (Slip Position), IST (Interior Surface Treatment), HD (Hardness), PC (Paste color), CR (Core), ND (Non Plastic Inclusion-Dominant), NO (Non Plastic Inclusion-Others), MA (Mica), SP (Surface Preparation), CD (Carved), CDP (Carved Position), PI, (Plastic I), PIP (Plastic I Position), PII (Plastic II), PIIP (Plastic II Position).

Appendix B.5: Coded rimsherds (< 3cm across) data by excavation unit and level

Unit	Level	TK	AG	TY	LS	HD	PC	CR	ND	NO	EST	IST
IO-B	1	1	2	102	1	1	3	4	2	0	0	0
IO-B	1	0.6	4	101	1	2	3	4	2	0	0	0
IO-B	1	1.1	5	501	1	3	1	0	1	0	0	0
IO-B	1	0.9	5	501	1	1	3	4	2	0	0	0
IO-B	1	0.8	5	501	1	2	1	3	1	2	0	0
IO-B	1	1	5	601	1	3	2	1	1	2	0	0
IO-B	1	0.6	5	601	1	1	2	0	3	1	0	0
IO-B	1	0.7	5	601	1	1	3	4	3	0	0	0
IO-B	1	0.8	5	604	1	3	1	0	1	0	0	0
IO-B	1	1.2	5	702	1	2	1	0	3	1	0	0
IO-B	1	1.3	5	705	1	3	1	0	1	0	0	0
IO-B	1	1.1	5	705	1	2	1	0	2	1	0	0
IO-B	3	0.9	5	501	1	1	2	0	2	0	0	1
IO-B	4	0.8	2	102	1	3	3	4	2	1	0	0
IO-B	4	1	2	102	1	3	1	0	1	0	0	0
IO-B	4	0.7	2	102	1	3	1	0	1	0	0	0
IO-B	4	0.6	2	102	1	2	1	1	3	2	0	0
IO-B	4	0.5	2	102	1	3	3	4	2	0	0	0
IO-B	4	0.8	2	102	1	3	3	4	2	0	1	1
IO-B	4	0.9	3	101	1	2	3	4	2	0	2	2
IO-B	4	0.9	4	101	1	2	1	0	1	2	0	0
IO-B	4	0.8	4	101	1	2	1	0	2	0	0	0
IO-B	4	1.3	4	203	1	5	3	4	1	2	0	0
IO-B	4	0.8	4	101	1	2	3	4	2	0	1	1
IO-B	4	0.6	4	101	1	3	1	0	2	0	2	0
IO-B	4	0.5	5	102	1	2	1	0	2	0	0	0
IO-B	4	0.8	5	102	1	2	1	0	1	3	0	0
IO-B	4	1.2	5	501	1	3	3	4	2	0	0	0
IO-B	4	1.2	5	501	1	2	1	3	2	0	0	0
IO-B	4	0.8	5	501	1	2	1	0	3	2	0	0
IO-B	4	0.6	5	601	1	2	1	0	1	3	0	0
IO-B	4	1.1	5	601	1	2	1	0	1	2	0	0
IO-B	4	0.5	5	601	1	3	1	0	2	0	0	0
IO-B	4	1	5	604	1	1	1	0	1	3	0	0
IO-B	4	1	5	604	1	2	2	0	1	0	0	0

Note: See appendix B.1 for code description. Sampling Fraction 100%. Variables: TK (Thickness), AG (Angle), TY (Type), HD (Hardness), PC (Paste color), CR (Core), ND (Non Plastic Inclusion-Dominant), NO (Non Plastic Inclusion-Others), EST (Exterior Surface Treatment), IST (Interior Surface Treatment),

Appendix B.5 (Cont.): Coded rimsherds (< 3cm across) data by excavation unit and level

Unit	Level	TK	AG	TY	LS	HD	PC	CR	ND	NO	EST	IST
IO-B	4	0.8	5	604	1	2	1	0	3	2	0	0
IO-B	4	0.9	5	702	1	1	2	3	2	0	0	0
IO-B	4	0.9	5	702	1	1	1	0	1	3	0	0
IO-B	4	0.8	5	702	1	2	1	0	1	0	0	0
IO-B	4	1.3	5	705	1	3	2	0	1	2	0	0
IO-B	4	0.7	5	705	1	2	1	0	1	0	0	0
IO-B	4	0.8	5	705	1	2	1	0	1	3	0	0
IO-B	4	0.8	5	604	1	2	3	4	1	0	1	1
IO-B	4	1.2	3	103	2	2	1	0	1	3	0	0
IO-B	4	0.7	5	605	4	2	2	3	2	0	0	0
IO-B	4	1.2	5	605	4	3	2	0	2	0	0	0
IO-B	4	1	5	605	4	2	2	0	1	3	0	0
IO-B	4	1	5	605	4	1	1	0	1	3	0	0
IO-B	4	0.7	5	605	4	2	2	2	3	2	3	1
IO-B	5	0.6	3	101	1	2	3	4	2	0	0	0
IO-B	5	0.7	4	102	1	1	2	4	1	2	0	0
IO-B	5	0.5	4	503	1	1	2	4	1	0	0	0
IO-B	5	0.6	4	604	1	3	3	4	1	3	0	0
IO-B	5	0.6	3	101	7	2	1	0	1	3	0	0
IO-B	5	1	5	501	7	3	4	4	1	3	1	0
IO-B	6	0.6	5	101	1	1	2	0	1	3	0	0
IO-B	6	1	5	701	1	3	1	0	1	0	0	0
IO-B	6	1.4	2	103	4	3	1	0	1	3	1	1
IO-B	6	0.6	2	202	5	3	3	4	2	0	0	0
IO-B	6	0.6	2	101	7	2	3	4	2	0	1	1
IO-B	6	0.6	4	501	7	2	2	5	2	0	0	0
IO-B	6	0.8	5	601	7	3	1	0	1	0	1	1
IO-B	8	0.9	3	404	1	3	3	4	1	0	0	0
IO-B	8	0.7	5	603	1	1	1	2	1	3	1	1
IO-B	8	0.8	4	203	5	3	3	4	2	0	0	0
IO-C	1	0.4	4	604	1	2	1	0	2	0	0	0
IO-C	1	0.7	4	202	1	2	2	0	1	3	1	1
IO-C	1	0.6	5	503	1	1	2	2	1	3	0	0
IO-C	1	0.5	5	503	1	2	1	3	2	0	0	0
IO-C	1	0.6	4	102	3	3	3	4	1	0	0	0

Note: See appendix B.1 for code description. Sampling Fraction 100%. Variables: TK (Thickness), AG (Angle), TY (Type), HD (Hardness), PC (Paste color), CR (Core), ND (Non Plastic Inclusion-Dominant), NO (Non Plastic Inclusion-Others), EST (Exterior Surface Treatment), IST (Interior Surface Treatment),

Appendix B.5 (Cont.): Coded rimsherds (< 3cm across) data by excavation unit and level

Unit	Level	TK	AG	TY	LS	HD	PC	CR	ND	NO	EST	IST
IO-C	2	0.8	2	101	1	2	1	0	1	0	0	0
IO-C	2	0.5	2	101	1	3	1	0	1	0	0	0
IO-C	2	1.3	5	501	1	1	1	0	1	3	0	0
IO-C	2	0.7	5	503	1	1	2	4	3	0	0	0
IO-C	2	0.5	5	601	1	2	1	3	2	3	0	0
IO-C	2	0.6	5	604	1	1	2	0	2	0	0	0
IO-C	2	1	5	604	1	2	1	0	1	3	0	0
IO-C	2	0.8	5	604	1	2	2	2	2	3	0	0
IO-C	2	1	5	501	1	3	1	0	1	0	0	0
IO-C	2	1	5	501	1	1	1	3	1	0	1	1
IO-C	2	1.1	3	103	2	3	2	3	1	0	0	0
IO-C	2	1	3	103	2	2	1	3	2	3	1	1
IO-C	3	1	2	101	1	2	1	0	1	0	0	0
IO-C	3	0.6	2	101	1	1	1	3	1	0	1	0
IO-C	3	1	5	503	1	2	1	0	1	0	0	0
IO-C	3	0.6	5	604	1	3	1	0	1	3	0	0
IO-C	4	0.5	2	102	1	3	3	4	1	2	0	0
IO-C	4	0.8	3	101	1	2	1	0	1	2	1	1
IO-C	4	0.6	3	101	1	2	2	0	1	0	2	2
IO-C	4	0.6	4	101	1	2	1	0	1	0	0	0
IO-C	4	0.5	4	101	1	2	1	0	2	0	0	0
IO-C	4	0.7	4	101	1	3	1	0	2	0	1	1
IO-C	4	1.6	5	501	1	2	1	0	1	0	0	0
IO-C	4	0.7	5	601	1	1	2	2	1	3	0	0
IO-C	4	1.1	5	604	1	1	2	1	1	3	0	0
IO-C	4	1	5	605	1	1	2	3	1	3	0	0
IO-C	4	0.9	5	705	1	2	1	3	1	3	0	0
IO-C	4	0.6	5	503	1	1	1	0	3	2	1	1
IO-C	4	1	5	702	1	1	3	4	1	3	1	1
IO-C	4	0.9	2	605	4	1	1	0	2	0	2	2
IO-C	5	0.9	2	102	1	2	3	4	2	0	0	0
IO-C	5	0.9	2	102	1	3	1	0	3	1	0	0
IO-C	5	0.7	2	102	1	3	1	0	1	2	0	0
IO-C	5	0.8	2	102	1	3	2	0	1	3	0	0
IO-C	5	0.6	2	102	1	2	1	0	2	0	0	0
IO-C	5	0.5	2	305	1	2	1	3	2	0	0	0

Note: See appendix B.1 for code description. Sampling Fraction 100%. Variables: TK (Thickness), AG (Angle), TY (Type), HD (Hardness), PC (Paste color), CR (Core), ND (Non Plastic Inclusion-Dominant), NO (Non Plastic Inclusion-Others), EST (Exterior Surface Treatment), IST (Interior Surface Treatment),

Appendix B.5 (Cont.): Coded rimsherds (< 3cm across) data by excavation unit and level

Unit	Level	TK	AG	TY	LS	HD	PC	CR	ND	NO	EST	IST
IO-C	5	0.7	3	101	1	3	3	4	1	2	0	0
IO-C	5	0.7	4	101	1	2	1	0	1	3	0	0
IO-C	5	0.6	4	101	1	3	3	4	2	0	0	0
IO-C	5	0.7	5	102	1	3	1	0	2	0	0	0
IO-C	5	1.2	5	501	1	2	1	3	1	2	0	0
IO-C	5	0.7	5	501	1	2	1	0	1	0	0	0
IO-C	5	0.8	5	503	1	3	1	0	1	3	0	0
IO-C	5	1	5	503	1	2	2	0	2	0	0	0
IO-C	5	0.9	5	601	1	2	1	3	2	0	0	0
IO-C	5	0.7	5	604	1	3	1	3	2	3	0	0
IO-C	5	0.8	5	604	1	2	1	0	1	3	0	0
IO-C	5	0.9	5	604	1	2	3	4	2	0	0	0
IO-C	5	1	5	705	1	2	2	0	1	0	0	0
IO-C	5	0.9	5	705	1	2	1	0	1	2	0	0
IO-C	5	0.8	5	601	1	1	2	3	1	2	0	0
IO-C	5	0.9	5	601	1	2	3	4	2	0	0	1
IO-C	5	0.9	5	604	1	3	1	3	1	2	0	1
IO-C	5	0.8	5	503	1	2	3	4	1	2	1	0
IO-C	5	0.9	5	702	1	2	1	3	1	0	1	0
IO-C	5	1.1	5	601	1	1	3	0	1	0	1	1
IO-C	5	0.7	5	601	1	3	3	4	1	2	1	1
IO-C	5	0.5	2	102	2	3	1	0	1	3	0	0
IO-C	6	0.7	2	102	1	3	3	4	2	0	0	0
IO-C	6	0.7	2	102	1	2	1	3	2	0	0	0
IO-C	6	0.7	2	305	1	3	1	0	2	3	0	0
IO-C	6	0.6	2	401	1	3	3	3	2	3	0	0
IO-C	6	0.8	2	401	1	2	3	4	1	3	1	1
IO-C	6	1.1	3	101	1	3	1	0	1	3	0	0
IO-C	6	0.8	4	101	1	1	1	0	1	2	0	0
IO-C	6	0.9	5	503	1	3	1	0	1	2	0	0
IO-C	6	0.8	5	601	1	3	1	0	2	0	0	0
IO-C	6	0.8	5	601	1	2	3	4	1	2	0	0
IO-C	6	0.6	5	601	1	2	3	4	2	0	0	0
IO-C	6	1	5	604	1	2	1	0	2	1	0	0
IO-C	6	0.8	5	604	1	2	1	0	1	2	0	0
IO-C	6	0.8	5	604	1	2	3	4	1	2	0	0

Note: See appendix B.1 for code description. Sampling Fraction 100%. Variables: TK (Thickness), AG (Angle), TY (Type), HD (Hardness), PC (Paste color), CR (Core), ND (Non Plastic Inclusion-Dominant), NO (Non Plastic Inclusion-Others), EST (Exterior Surface Treatment), IST (Interior Surface Treatment),

Appendix B.5 (Cont.): Coded rimsherds (< 3cm across) data by excavation unit and level

Unit	Level	TK	AG	TY	LS	HD	PC	CR	ND	NO	EST	IST
IO-C	6	1	5	702	1	2	1	0	2	0	0	0
IO-C	6	1	5	503	1	3	3	4	2	0	1	1
IO-C	6	0.7	6	500	1	3	1	0	1	3	0	0
IO-C	6	0.9	4	306	3	2	1	3	2	0	0	0
IO-C	6	0.6	4	101	5	2	1	0	2	0	0	0
IO-C	6	1	4	202	5	2	2	0	2	3	0	0
IO-C	7	0.5	4	101	1	2	2	2	1	0	0	0
IO-C	7	0.9	5	603	1	2	2	3	1	3	0	0
IO-D	1	0.76	3	102	1	1	3	4	2	3	1	1
IO-D	1	0.6	5	601	1	2	2	1	2	0	0	0
IO-D	1	0.7	5	601	1	3	2	0	1	0	3	0
IO-D	1	1	5	601	1	3	1	0	1	3	3	0
IO-D	2	0.9	2	404	1	3	3	4	2	0	1	0
IO-D	2	0.8	3	101	1	3	2	3	2	1	1	1
IO-D	2	0.7	5	201	1	2	2	0	2	0	0	0
IO-D	2	0.7	5	503	1	2	1	2	2	0	0	0
IO-D	2	0.9	5	503	1	1	3	4	2	1	0	0
IO-D	2	0.8	5	604	1	3	2	0	2	0	0	0
IO-D	2	0.7	5	604	1	3	1	0	2	0	0	0
IO-D	2	0.8	5	604	1	1	1	3	1	2	0	0
IO-D	2	0.7	5	705	1	2	2	2	1	0	0	0
IO-D	2	0.6	5	102	1	2	1	0	1	2	0	0
IO-D	2	1	5	101	1	3	1	1	1	2	1	1
IO-D	2	0.7	5	604	1	3	3	4	1	0	1	1
IO-D	2	1.1	5	503	1	3	2	0	2	0	2	2
IO-D	2	0.8	5	503	1	2	1	2	2	3	3	0
IO-D	2	0.9	4	604	3	2	2	0	2	1	1	0
IO-D	3	1.1	4	706	1	3	1	0	2	0	0	0
IO-D	3	0.8	5	601	1	2	2	3	1	2	0	0
IO-D	3	0.8	5	702	1	2	3	4	1	3	0	0
IO-D	4	0.9	2	401	1	1	3	4	1	3	0	0
IO-D	4	0.8	2	402	1	3	3	4	1	0	1	1
IO-D	4	0.5	5	101	1	2	1	0	1	3	0	0
IO-D	4	0.8	5	503	1	1	2	0	1	0	0	0
IO-D	4	0.9	5	503	1	1	1	3	3	2	0	0
IO-D	4	6	5	503	1	2	1	3	2	1	0	0

Note: See appendix B.1 for code description. Sampling Fraction 100%. Variables: TK (Thickness), AG (Angle), TY (Type), HD (Hardness), PC (Paste color), CR (Core), ND (Non Plastic Inclusion-Dominant), NO (Non Plastic Inclusion-Others), EST (Exterior Surface Treatment), IST (Interior Surface Treatment),

Appendix B.5 (Cont.): Coded rimsherds (< 3cm across) data by excavation unit and level

Unit	Level	TK	AG	TY	LS	HD	PC	CR	ND	NO	EST	IST
IO-D	4	0.7	5	601	1	3	1	0	3	1	0	0
IO-D	4	1	5	604	1	1	1	2	2	3	0	0
IO-D	4	0.9	5	604	1	2	1	0	2	1	0	0
IO-D	4	1.3	5	604	1	2	2	3	3	1	0	0
IO-D	4	0.8	5	604	1	2	3	4	2	0	0	0
IO-D	4	0.8	5	604	1	3	2	3	3	1	0	1
IO-D	4	0.8	5	101	1	1	1	0	2	1	1	1
IO-D	4	0.6	5	101	1	3	3	4	2	0	1	1
IO-D	4	1	5	604	1	2	1	2	2	0	3	0
IO-D	4	1	5	102	3	2	2	3	2	3	0	0
IO-D	4	0.7	5	605	4	2	1	0	2	0	0	0
IO-D	4	0.9	5	605	4	3	1	4	1	0	1	1
IO-D	4	1	5	101	5	2	1	0	1	3	0	0
IO-D	5	0.8	3	203	1	3	3	4	2	0	1	1
IO-D	5	1	5	503	1	2	1	0	2	0	0	0
IO-D	5	0.7	5	503	1	2	3	4	2	1	0	0
IO-D	5	0.7	5	503	1	1	1	1	2	0	0	0
IO-D	5	0.6	5	503	1	1	1	3	3	0	0	0
IO-D	5	0.7	5	601	1	2	1	0	1	0	0	0
IO-D	5	0.9	5	602	1	3	1	3	1	0	0	0
IO-D	5	0.7	5	604	1	1	1	0	3	2	0	0
IO-D	5	0.8	5	503	1	3	3	4	1	3	1	1
IO-D	5	0.8	5	503	1	1	1	0	2	1	1	1
IO-D	5	0.6	5	604	1	2	3	4	2	0	1	1
IO-D	5	0.7	5	102	3	3	2	0	3	2	0	0
IO-D	5	1	5	102	3	2	1	0	2	0	0	0
IO-D	5	0.6	5	102	3	1	1	1	2	0	2	2
IO-D	5	0.8	5	605	4	3	2	3	2	0	0	0
IO-D	5	1.1	5	203	5	2	1	0	1	2	0	0
IO-D	6	0.8	3	101	1	3	1	0	1	2	0	0
IO-D	6	0.9	4	102	1	1	1	0	1	3	0	0
IO-D	6	0.9	4	102	1	3	3	4	2	0	0	0
IO-D	6	0.8	4	101	1	3	2	4	1	2	0	1
IO-D	6	0.9	4	101	1	2	2	0	1	3	1	1
IO-D	6	0.7	5	102	1	3	3	4	1	2	0	0
IO-D	6	0.9	5	301	1	3	1	0	1	0	0	0

Note: See appendix B.1 for code description. Sampling Fraction 100%. Variables: TK (Thickness), AG (Angle), TY (Type), HD (Hardness), PC (Paste color), CR (Core), ND (Non Plastic Inclusion-Dominant), NO (Non Plastic Inclusion-Others), EST (Exterior Surface Treatment), IST (Interior Surface Treatment),

Appendix B.5 (Cont.): Coded rimsherds (< 3cm across) data by excavation unit and level

Unit	Level	TK	AG	TY	LS	HD	PC	CR	ND	NO	EST	IST
IO-D	6	1	5	503	1	3	1	0	1	2	0	0
IO-D	6	0.6	5	503	1	2	1	0	1	3	0	0
IO-D	6	0.8	5	601	1	2	1	3	1	3	0	0
IO-D	6	1	5	702	1	2	1	3	1	3	0	1
IO-D	6	1	5	503	1	1	3	4	1	3	1	1
IO-D	6	0.8	5	601	1	1	3	4	1	3	1	1
IO-D	6	0.6	5	601	1	2	3	4	2	3	1	1
IO-D	6	0.8	5	604	1	2	3	4	2	0	1	1
IO-D	6	0.8	5	702	1	1	3	4	1	0	1	1
IO-D	6	0.8	5	705	1	3	1	3	3	2	1	1
IO-D	6	0.6	5	802	1	2	1	0	1	2	1	1
IO-D	6	1.1	5	604	1	2	3	4	2	0	2	2
IO-D	6	0.7	5	503	1	3	3	4	2	1	3	3
IO-D	6	1	3	103	2	1	1	0	1	3	0	0
IO-D	6	0.8	5	102	3	2	1	0	1	2	0	0
IO-D	6	0.8	5	305	3	1	3	4	2	0	0	0
IO-D	6	0.8	4	605	4	2	1	0	1	0	1	1
IO-D	7 pit 1	0.6	2	101	1	2	3	4	1	2	1	1
IO-D	7 pit 1	0.7	5	601	1	1	1	0	1	0	0	0
IO-D	7 pit 1	0.7	5	604	1	1	3	4	2	0	0	0
IO-D	7 pit 1	0.7	5	604	1	2	1	0	2	0	0	0
IO-D	7 pit 1	1	5	501	1	1	3	4	2	0	1	1
IO-D	7 pit 2	0.9	2	101	1	2	1	3	1	0	1	1
IO-D	7 pit 2	0.8	2	103	1	2	2	0	3	0	1	1
IO-D	7 pit 2	0.7	5	601	1	1	1	0	3	2	0	0
IO-D	7 pit 2	0.8	5	604	1	2	2	0	1	3	0	0
IO-D	7 pit 2	1	5	705	1	2	2	0	1	3	0	0
IO-D	7 pit 2	0.9	5	705	1	3	1	0	3	2	1	1
IO-D	7 pit 2	0.6	5	601	1	1	3	4	2	3	3	1
IO-D	7 pit 2	0.9	5	306	4	1	3	4	2	3	2	2
IO-D	7 pit 2	7.3	4	101	7	2	1	3	2	0	0	0
IO-D	7 pit 2	12.46	4	102	7	3	4	3	2	0	1	1
OO-A	2	6.98	1	101	1	3	1	3	1	3	0	0
OO-A	2	7.86	4	604	1	2	1	3	2	0	0	0
OO-A	2	7.4	4	101	1	2	1	1	1	2	0	1
OO-A	2	5.81	4	101	1	3	3	4	2	0	2	2

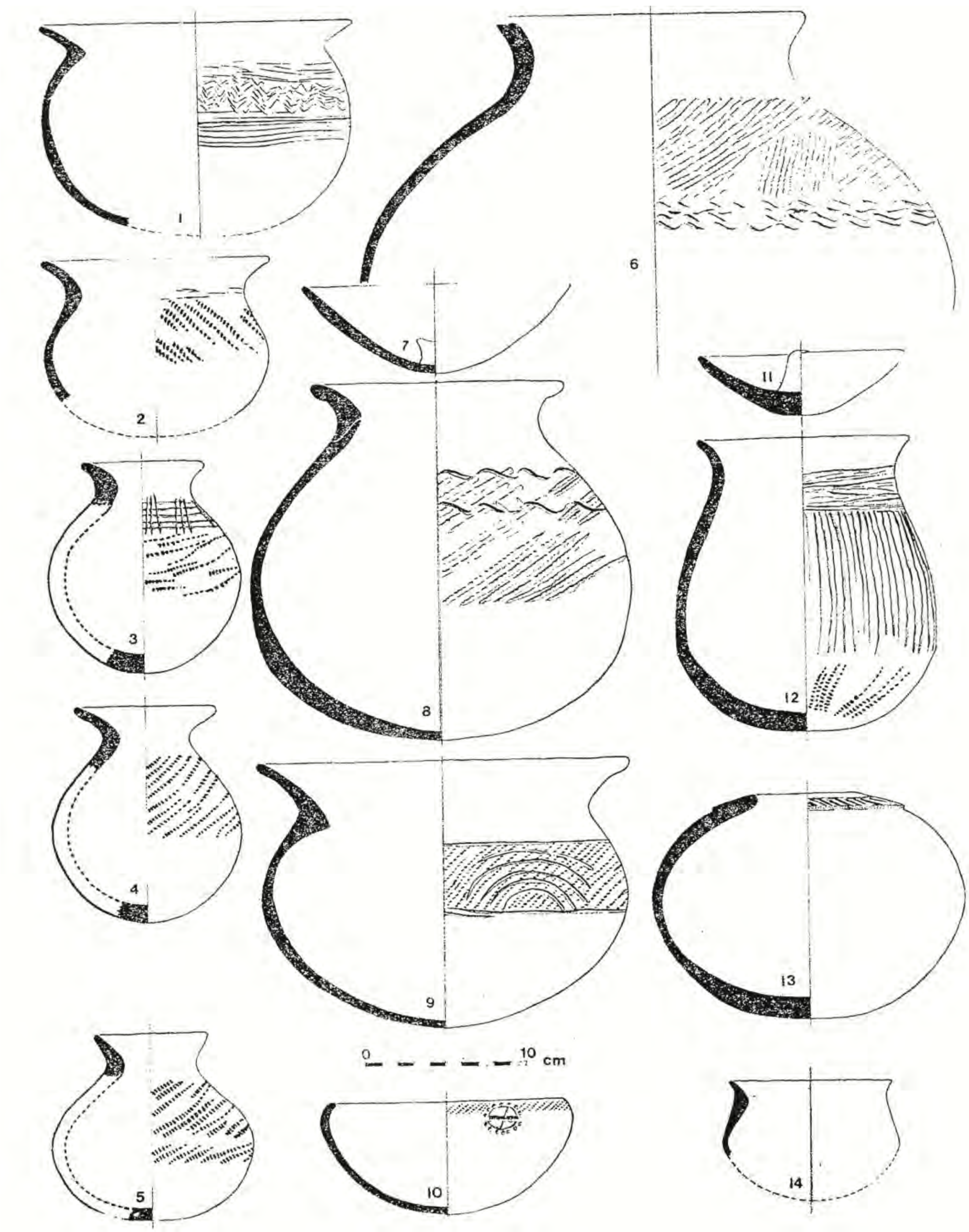
Note: See appendix B.1 for code description. Sampling Fraction 100%. Variables: TK (Thickness), AG (Angle), TY (Type), HD (Hardness), PC (Paste color), CR (Core), ND (Non Plastic Inclusion-Dominant), NO (Non Plastic Inclusion-Others), EST (Exterior Surface Treatment), IST (Interior Surface Treatment),

Appendix B.5 (Cont.): Coded rimsherds (< 3cm across) data by excavation unit and level

Unit	Level	TK	AG	TY	LS	HD	PC	CR	ND	NO	EST	IST
OO-A	2	5.33	5	602	1	1	1	1	2	0	0	0
OO-A	2	6.4	5	604	1	2	3	4	1	0	0	0
OO-A	2	7.33	5	604	1	2	3	4	2	0	0	0
OO-A	2	6.53	5	602	1	2	1	0	1	3	1	1
OO-A	2	8.27	1	101	7	2	3	4	2	0	0	0
OO-A	2	7.59	5	602	7	2	1	3	2	0	1	1
OO-A	3	7.24	4	501	1	1	1	3	1	2	1	1
OO-A	3	18.35	4	704	1	3	1	0	1	3	1	1
OO-A	3	6.46	4	602	7	1	1	1	2	0	1	1
OO-A	3	5.78	5	602	7	1	1	0	1	2	0	0
OO-A	4	7.62	5	601	1	3	1	3	2	1	0	0
OO-A	4	7.22	5	602	1	2	1	0	3	1	0	0
OO-A	4	5.75	5	701	7	1	1	0	1	2	0	0
OO-A	5	6.96	2	101	1	3	4	0	3	2	0	0
OO-A	5	5.95	5	602	1	3	1	0	2	3	0	0
OO-A	6	7.64	1	101	1	3	1	0	1	3	1	1
OO-A	6	7.79	3	101	1	3	4	3	1	2	0	0
OO-A	6	7.89	5	702	1	2	1	0	1	3	1	1
OO-A	6	8.15	5	706	3	2	1	0	1	3	0	0
OO-A	6	6.37	2	202	5	3	3	4	2	0	0	0
OO-A	6	6.73	5	602	7	1	3	4	1	2	0	0
OO-A	7	9.33	5	503	1	2	4	4	2	0	0	0
OO-A	7	9.09	5	604	1	1	3	4	1	2	0	0
OO-A	7	8.47	5	701	1	2	1	2	2	3	0	0

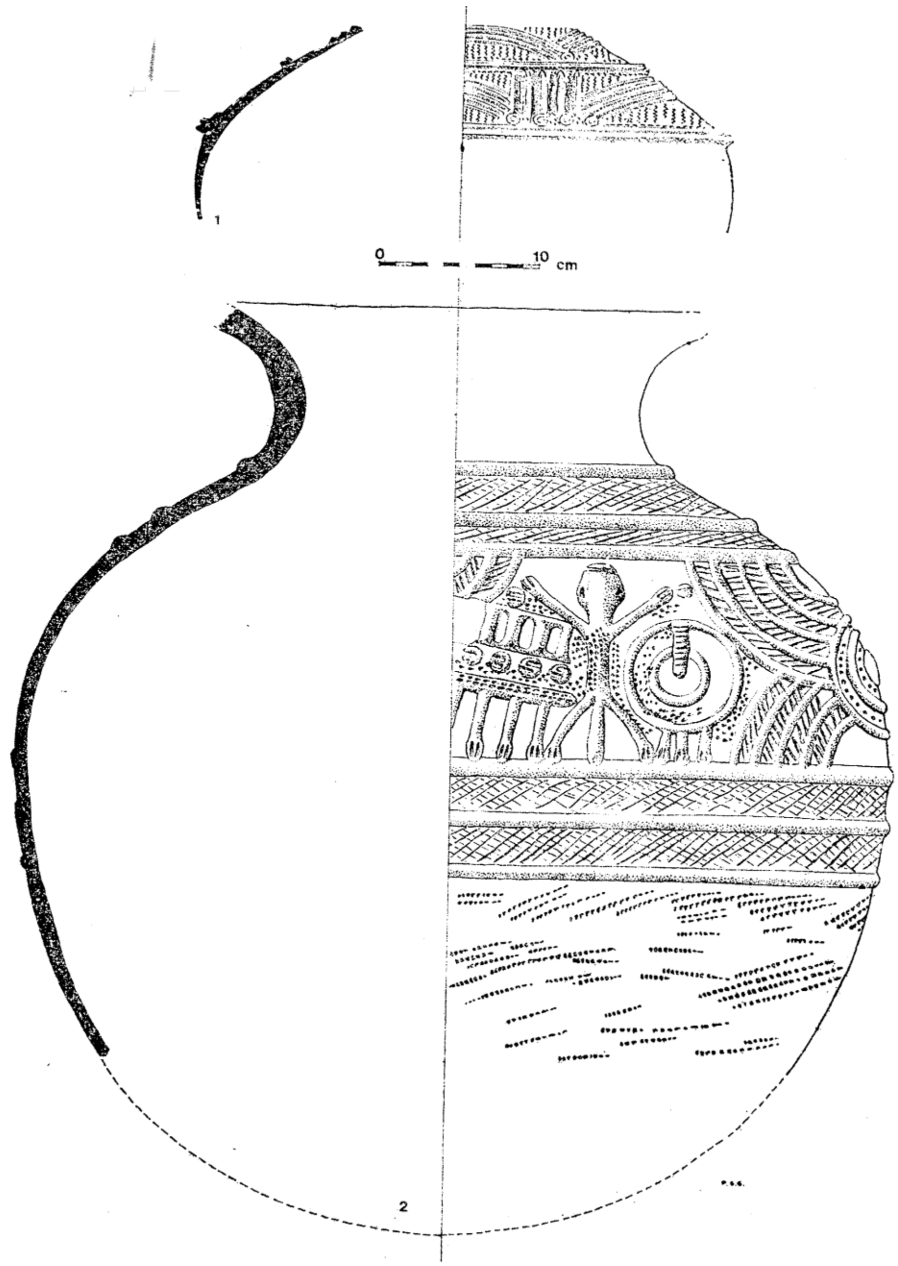
Note: See appendix B.1 for code description. Sampling Fraction 100%. Variables: TK (Thickness), AG (Angle), TY (Type), HD (Hardness), PC (Paste color), CR (Core), ND (Non Plastic Inclusion-Dominant), NO (Non Plastic Inclusion-Others), EST (Exterior Surface Treatment), IST (Interior Surface Treatment),

Appendix B. 6: Peter Garlake's (1974, 1977) Ile-Ife pottery types and their variants.



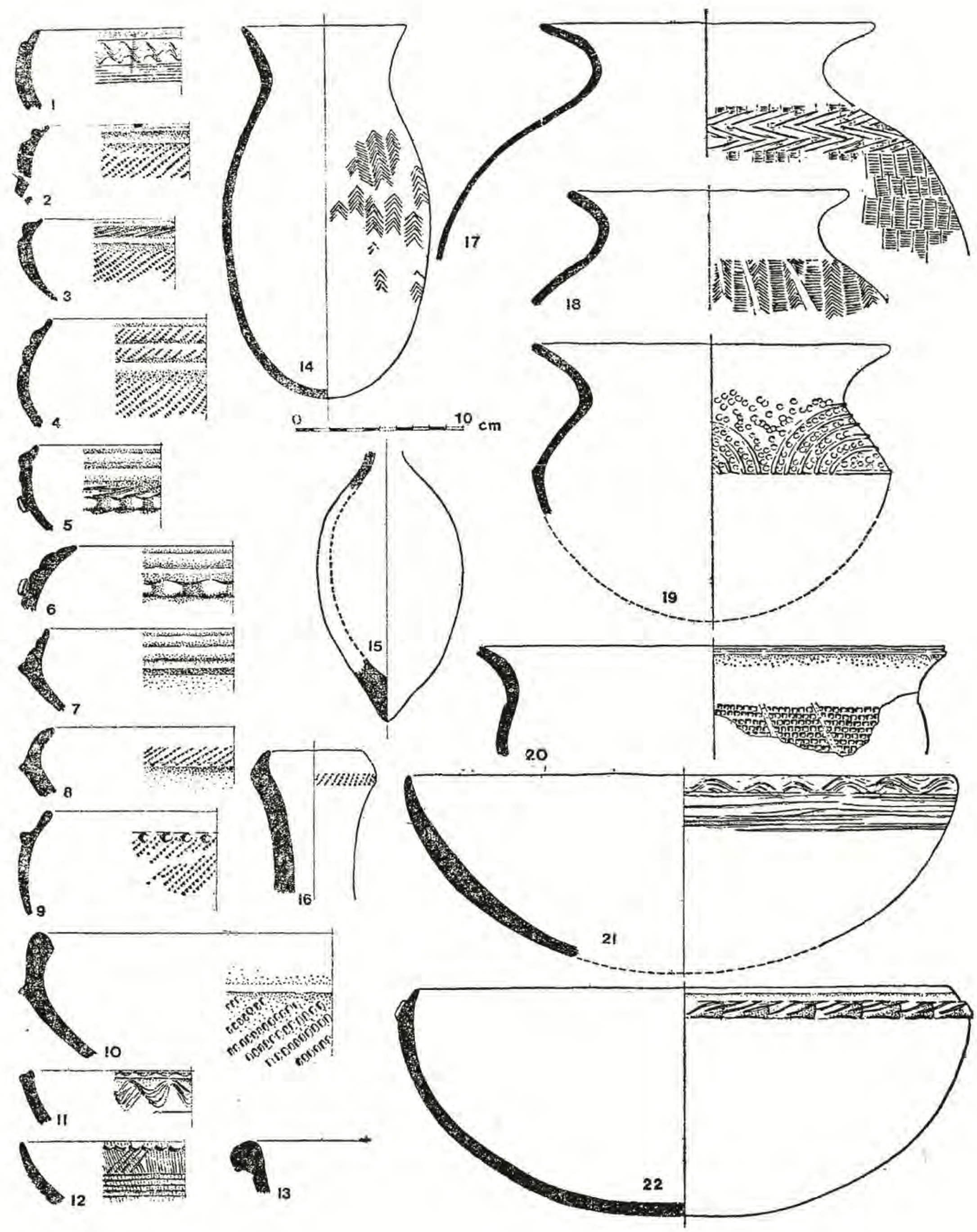
Note: Numbers are from Garlake's (1977:78) original work (Fig. 9)

Appendix B. 6 (Cont.): Peter Garlake's (1974, 1977) Ile-Ife pottery types and their variants.



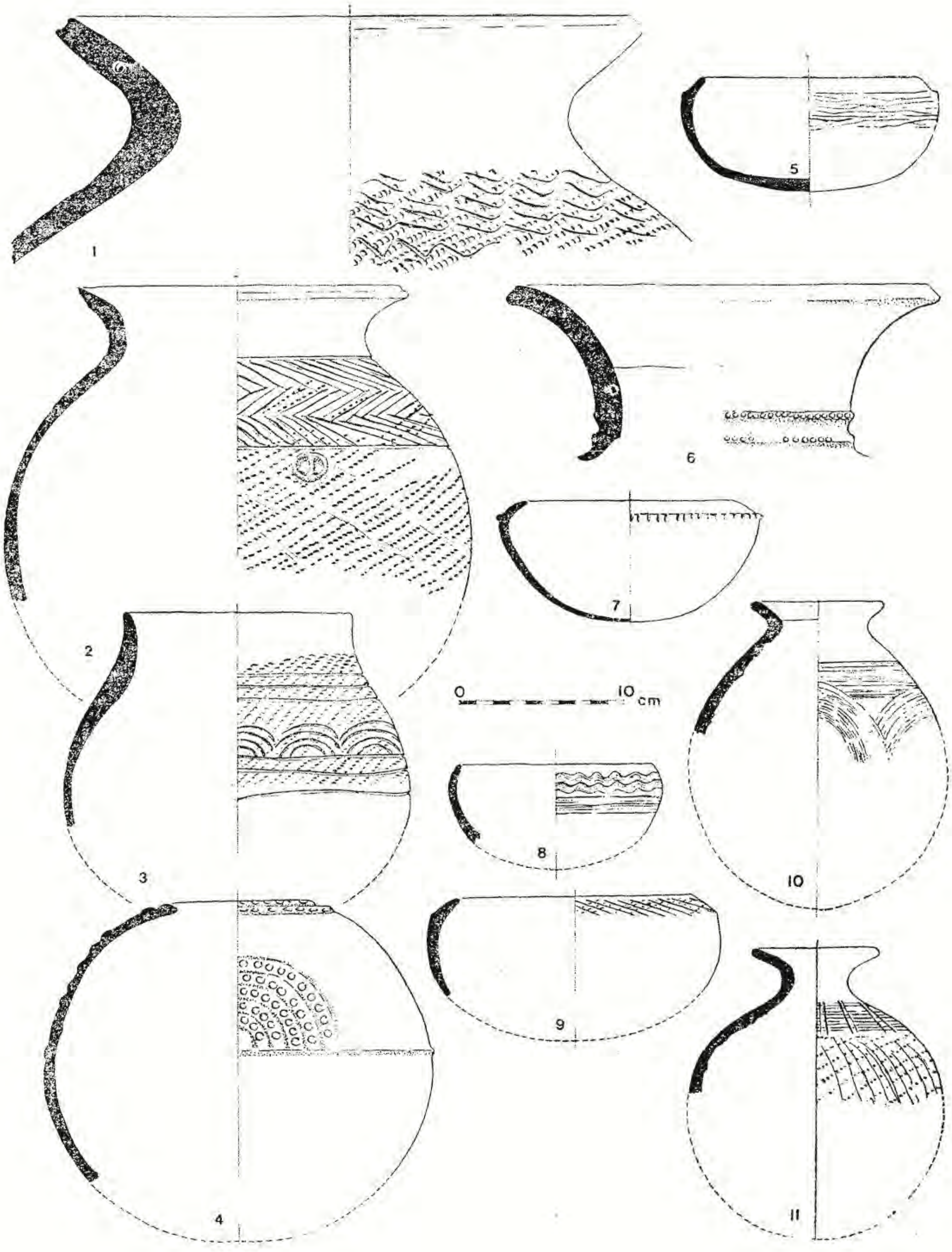
Note: Numbers are from Garlake's (1977:81) original work (Fig. 12)

Appendix B. 6 (Cont.): Peter Garlake's (1974, 1977) Ile-Ife pottery types and their variants.



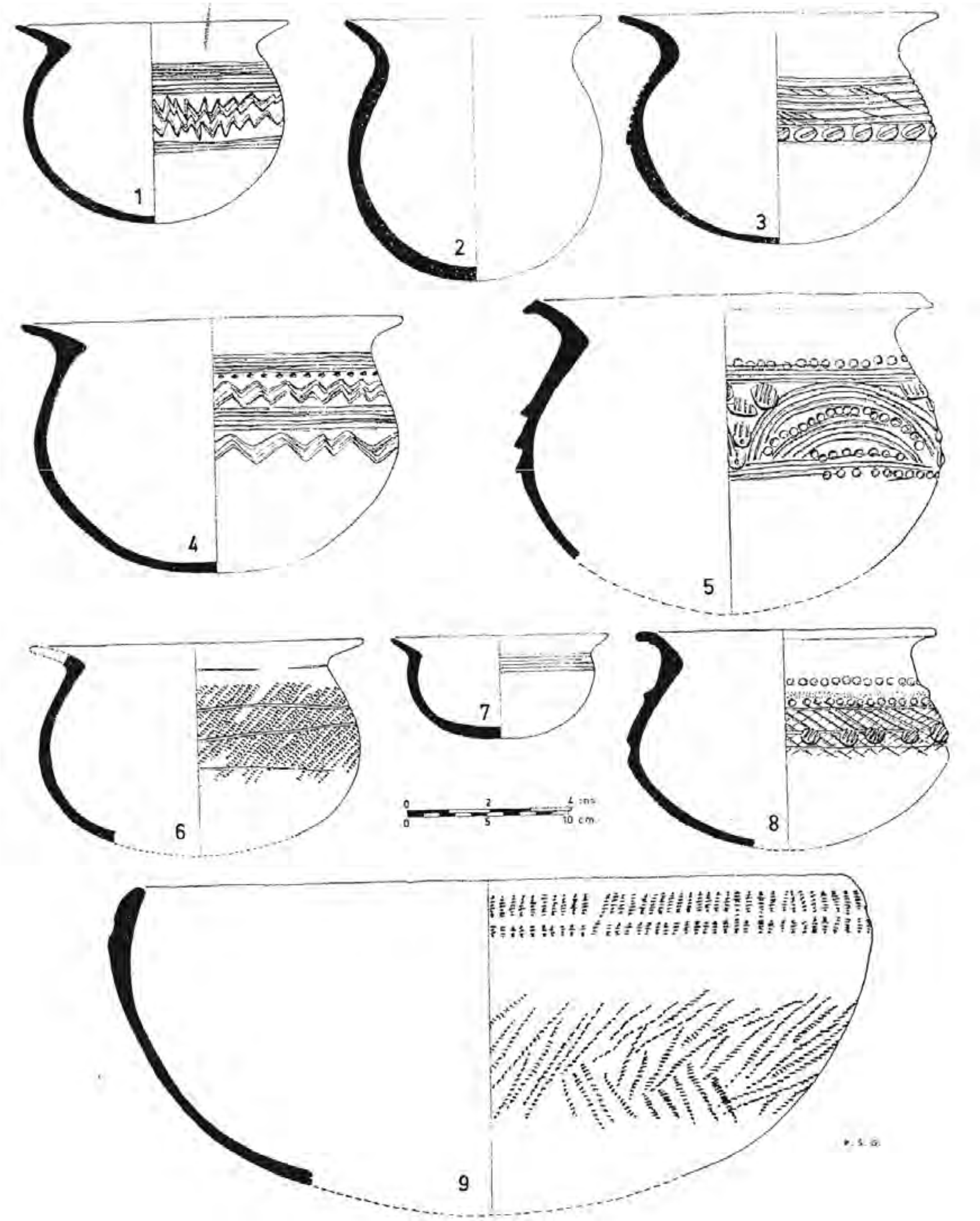
Note: Numbers are from Garlake's (1977:79) original work (Fig. 10)

Appendix B. 6 (Cont.): Peter Garlake's (1974, 1977) Ile-Ife pottery types and their variants.



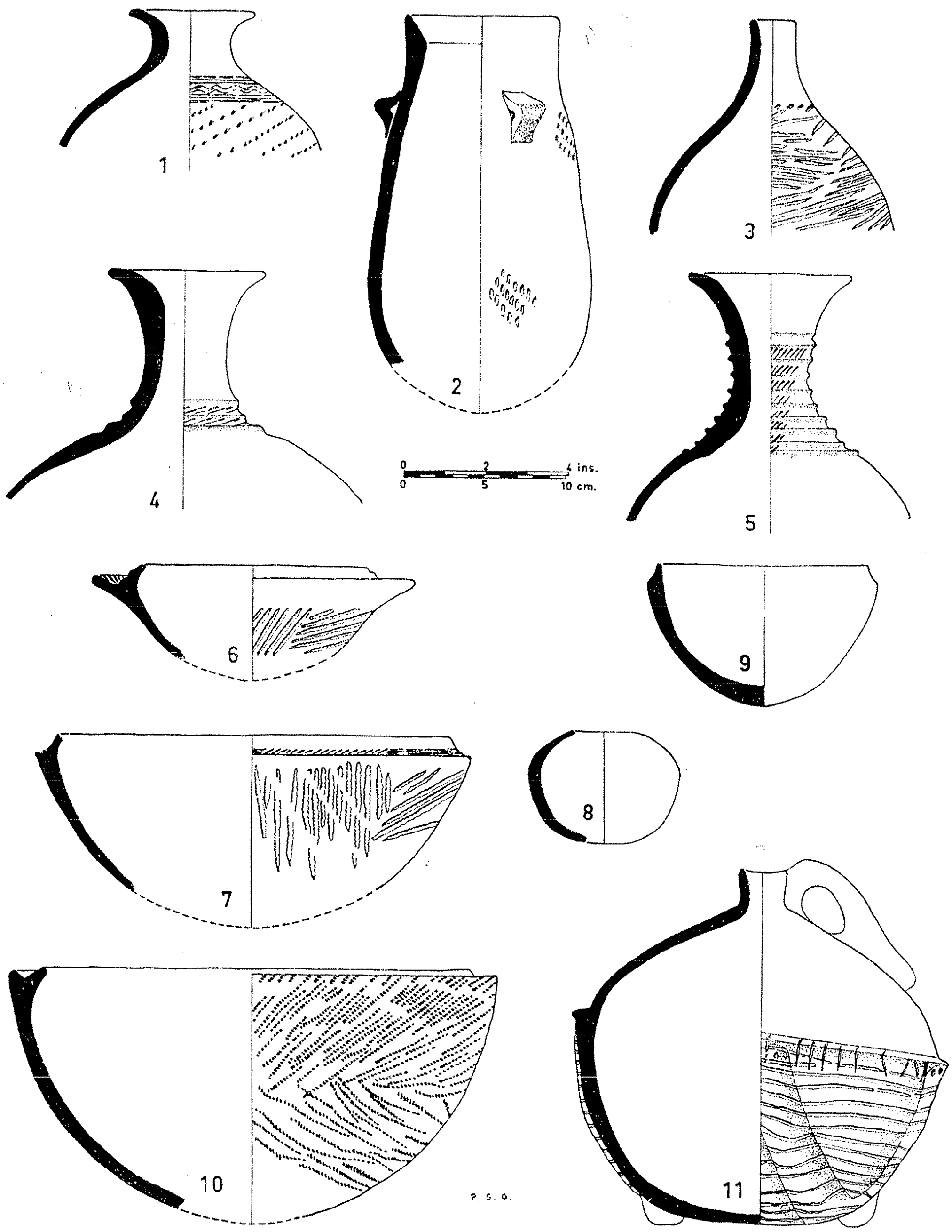
Note: Numbers are from Garlake's (1977:80) original work (Fig. 11)

Appendix B. 6 (Cont.): Peter Garlake's (1974, 1977) Ile-Ife pottery types and their variants



Note: Numbers are from Garlake's (1974: 137) original work (Fig. 8)

Appendix B. 6 (Cont.): Peter Garlake's (1974, 1977) Ile-Ife pottery types and their variants.



Note: Numbers are from Garlake's (1974: 138) original work (Fig. 9)

Appendix C

Appendix C.1: Distribution of Stone Artifacts by excavation unit and levels

Unit	Levels	Class	Granite	Quartz	Quartzite	Comments
IO-A	2	Flakes	-	x	-	2 pieces
IO-A	3	GSF	x	-	-	Discoloration presence
IO-A	3	Flakes	-	X	-	4 Pieces
IO-A	4	Flakes	-	X	-	3 Pieces
IO-B	2	GSF	-	-	X	
IO-B	3	GSF	-	-	X	
IO-B	4	Pebble	-	-	X	
IO-B	4	Boulder/Slab	-	-	X	
IO-B	4	Fragments	-	-	X	2 pieces
IO-B	6	GSF (upper)	-	-	X	
IO-B	6	Fragments	-	-	X	5 pieces
IO-B	7	Fragments	-	-	X	10 Pieces
IO-B	7	Pebble	-	-	X	3 Pieces
IO-B	8	Fragments	-	-	X	
IO-D	2	Fragments	-	-	X	
IO-D	3	Fragments	-	-	X	
IO-D	4	Fragments	-	X	-	3 Pieces
IO-D	4	Pebble	-	-	X	
IO-D	5	Fragments	-	-	X	4 Pieces
IO-D	6	Muller	-	-	X	
IO-D	6	Boulder/Slab	X	-	-	Discoloration presence
IO-D	6	GSF	X	-	-	Worn-out completely
IO-D	6	GSF	X	-	-	Worn-out completely
IO-D	7 Pit 2	GSF (upper)	X	-	-	Discoloration presence
IO-D	7 Pit 2	GSF	X	-	-	Slight coloration
IO-D	7 Pit 2	Boulder/Slab	X	-	-	Discoloration presence
IO-D	7 Pit 2	Fragments	-	-	X	5 pieces
IO-C	4	Flakes	-	X		3 Pieces
IO-C	5	Boulder/Slab	X	-	-	Discoloration presence
IO-C	5	Fragments	-	-	X	4 Pieces
IO-C	5	Boulder/Slab	X	-	-	Discoloration presence
IO-C	6	GSF	X	-	-	Discoloration presence
IO-C	7	Fragments	-	-	X	
OO-A	2	Muller	-	-	X	
IO-E	2	Boulder/Slab	x	-	-	Discoloration presence

Note: X (Presence), - (Absence), GSF (Grinding Stone Fragment)

Appendix D

Appendix D. 1: Description and provenience of the glass samples analyzed by LA-ICP-MS

Unit	Level	ID #	Type	Length (mm)	Diameter (mm)	Shape	Color	End Treatment	Comments
IO-D	5	IF-0001	Bead	3.9	2.4	Tube	Blue	Rounded end	
IO-D	4	IF-0002	Bead	10.5	2.2	Tube	Blue	Snapped end	
IO-C	7	IF-0003	Bead	11.4	2.3	Tube	Blue	Snapped end	
IO-C	7	IF-0004	Bead	7.9	2.9	Tube	Blue	Snapped end	
IO-B	4	IF-0005	Bead	13.8	2.3	Tube	Blue	Snapped end	
IO-B	4	IF-0006	Bead	5.5	3.6	Tube	Blue	Rounded end	
IO-C	4	IF-0007	Bead	5.6	3.8	Tube	Pale Blue	Rounded end	
IO-B	4	IF-0008	Bead	3.6	4.6	Cylinder	Blue	Snapped end	
IO-B	4	IF-0009	Bead	4.6	5.2	Cylinder	Blue	Rounded end	
IO-D	4	IF-0010	Bead	4.3	6.3	Cylinder	Blue	Rounded end	
IO-D	6	IF-0011	Bead	3.8	5.2	Cylinder	Blue	Snapped end	
IO-C	7	IF-0012	Bead	3.3	5	Cylinder	Blue	Rounded end	
IO-C	7	IF-0013	Bead	5.3	7.1	Cylinder	Pale Blue	Snapped end	
IO-D	5	IF-0014	Bead	1.3	3.4	Cylinder	Pale Blue	Snapped end	
IO-C	7	IF-0015	Bead	0.9	3	Oblate	Blue	Rounded end	
IO-C	7	IF-0016	Bead	1.6	3.2	Oblate	Blue	Rounded end	
IO-D	4	IF-0017	Bead	2	3.7	Oblate	Blue	Rounded end	
IO-D	4	IF-0018	Bead	2.1	3.6	Oblate	Blue	Rounded end	
IO-B	4	IF-0019	Bead	1.7	4.6	Oblate	Blue	Rounded end	
IO-B	4	IF-0020	Bead	1.7	4.6	Oblate	Blue	Rounded end	
IO-E	3	IF-0021	Cane	5.7	2	Cane	Red	Snapped end	No perforation
IO-B	5	IF-0022	Cane	8.9	1.8	Cane	Red	Snapped end	No perforation

Appendix D. 1 (Cont.): Description and provenience of the glass samples analyzed by LA-ICP-MS

Unit	Level	ID #	Type	Length (mm)	Diameter (mm)	Shape	Color	End Treatment	Comments
IO-D	4	IF-0023	Cane	15.9	2.6	Cane	Red	Snapped end	No perforation
IO-C	6	IF-0024	Cane	11	1.7	Cane	Red	Snapped end	No perforation
IO-D	4	IF-0025	Bead	5.7	1.9	Tube	Red	Rounded end	
IO-D	4	IF-0026	Bead	6.7	2.9	Tube	Striped	Snapped end	Red stripes on clear core
IO-C	6	IF-0027	Bead	6	5	Tube	Red	Snapped end	
IO-C	6	IF-0028	Bead	2.5	2.7	Cylinder	coated	Rounded end	Red coating on clear core
IO-C	6	IF-0029	Bead	1.8	2.8	Cylinder	coated	Snapped end	Red coating on clear core
IO-E	3	IF-0030	Bead	3.5	4.7	Cylinder	Clear	Snapped end	
IO-B	1	IF-0031	Bead	3.7	4.9	Cylinder	Clear	Snapped end	
IO-D	4	IF-0032	Bead	18.1	3.3	Tube	Clear	Snapped end	
IO-C	5	IF-0033	Bead	5.8	4.2	Tube	Striped	Rounded end	Red spiral on clear core
IO-C	6	IF-0034	Bead	3.8	5	Cylinder	Clear	Rounded end	
IO-C	6	IF-0035	Bead	2.3	2.8	Cylinder	Yellow	Rounded end	
IO-C	5	IF-0036	Bead	3	5.1	Cylinder	coated	Snapped end	Red coating on clear core
IO-C	6	IF-0037	Bead	3.2	3.2	Cylinder	Striped	Snapped end	White on pale blue core
IO-C	6	IF-0038	Bead	2.9	5.8	Cylinder	Striped	Snapped end	white and dark red on clear core
IO-C	4	IF-0039	Bead	5.8	3.5	Tube	Striped	Snapped end	Red, yellow, and black on blue core
IO-D	4	IF-0040	Bead			Fused	Yellow	Rounded end	Two oblate beads fused on the surface
IO-D	4	IF-0041	Bead	12.3	2.5	Tube	Yellow	Snapped end	
IO-B	4	IF-0042	Bead	3.3	4	Cylinder	Yellow	Rounded end	

Appendix D. 1 (Cont.): Description and provenience of the glass samples analyzed by LA-ICP-MS

Unit	Level	ID #	Type	Length (mm)	Diameter (mm)	Shape	Color	End Treatment	Comments
IO-D	5	IF-0043	Bead	6.4	4.1	Tube	Green	Rounded end	
IO-D	6	IF-0044	Bead	3.3	3.4	Cylinder	Striped	Rounded end	Red on blue core
IO-D	6	IF-0045	Bead	3.4	5.9	Cylinder	Striped	Snapped end	White slanted on blue core
IO-C	6	IF-0046	Bead	2.2	3.1	Cylinder	Green	Snapped end	
IO-C	4	IF-0047	Bead	1.9	3.5	Oblate	Gray/Black	Rounded end	
IO-D	6	IF-0048	Bead	5.9	5.8	Tube	Striped	Snapped end	Red on yellow on clear core
IO-C	4	IF-0049	Bead	5.6	4.5	Tube	Blue	Rounded end	
IO-B	4	IF-0050	Bead	4.2	3.4	Tube	Green	Rounded end	
IO-B	5	IF-0051	Bead	2.9	3.4	Cylinder	coated	Rounded end	Red coating on clear core
IO-D	7	IF-0052	Crucible glass				Pale Blue		Fragment from Crucible
IO-D	5	IF-0053	Crucible glass				Blue		Fragment from Crucible
IO-A	4	IF-0054	Crucible glass				Green		Fragment from Crucible
IO-D	7	IF-0055	Crucible glass				Yellow-Green		Fragment from Crucible
IO-D	6	IF-0056	Crucible glass				Gray/Black		Fragment from Crucible
IO-B	4	IF-0057	Crucible glass				Red		Fragment from Crucible
IO-D	7	IF-0058	Crucible glass				Red		Fragment from Crucible

Appendix D. 1 (Cont.): Description and provenience of the glass samples analyzed by LA-ICP-MS

Unit	Level	ID #	Type	Length (mm)	Diameter (mm)	Shape	Color	End Treatment	Comments
IO-B	4	IF-0059	Debris				Pale Blue		Waster
IO-B	4	IF-0060	Debris				Blue		Waster
IO-B	4	IF-0061	Debris				Yellow-Green		Waster
IO-B	4	IF-0062	Debris				Pale Blue		Waster
IO-C	4	IF-0063	Debris				Clear		Waster
IO-C	4	IF-0064	Debris				Pale Blue		Waster
IO-C	4	IF-0065	Debris				Green		Waster
IO-C	5	IF-0066	Debris				Blue		Waster
IO-C	5	IF-0067	Debris				Green		Waster
IO-C	5	IF-0068	Debris				Clear		Waster
OO-A	2	IF-0069	Bead	4.3	4.2	Cylinder	coated	Rounded end	Red coating on clear core
OO-A	4	IF-0070	Bead	19.5	5.5	Tube	Clear	Snapped end	
IO-D	6	IF-0071	VPD						Fragment of vitrified production debris

APPENDIX D.2

Elemental Analysis Facility
Field Museum of Natural History

LA-ICP-MS analysis of African glass beads

Principal Investigator:

Abidemi Babatunde Babalola

Objects:

Glass samples from Igbo Olokun, Nigeria

Operator of the LA-ICP-MS:

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Author of this document:

Laure Dussubieux

Attached document(s):

Table of results: Table 1.xls

Experimental

The analyses were carried out at the Field Museum of Natural History in Chicago, USA, with a Varian (now Bruker) Inductively Coupled Plasma - Mass Spectrometer (ICP-MS) connected to a New Wave UP213 laser for direct introduction of solid samples.

The parameters of the ICP-MS are optimized to ensure a stable signal with a maximum intensity over the full range of masses of the elements and to minimize oxides and double ionized species formation (XO^+/X^+ and $X^{++}/X^+ < 1$ to 2 %). For that purpose the argon flows, the RF power, the torch position, the lenses, the mirror and the detector voltages are adjusted using an auto-optimization procedure.

For better sensitivity, helium is used as a gas carrier in the laser. The choice of the parameters of the laser ablation not only will have an effect on the sensitivity of the method and the reproducibility of the measurements but also on the damage to the sample. To be able to determine elements with concentrations in the range of ppm and below while leaving a trace on the surface of the sample invisible to the naked eye, we use the single point analysis mode with a laser beam diameter of 80 μm, operating at 70 % of the laser energy (0.2 mJ) and at a pulse frequency of 15 Hz. A pre-ablation time of 20 s is set in order, first, to eliminate the transient part of the signal and, second, to be sure that a possible surface contamination or corrosion does not affect the results of the analysis. For each glass sample, the average of four measurements corrected from the blank is considered for the calculation of concentrations.

To improve reproducibility of measurements, the use of an internal standard is required to correct possible instrumental drifts or changes in the ablation efficiency. The element chosen as internal standard has to be present in relatively high concentration so its measurement is as accurate as possible. In order to obtain absolute concentrations for the analyzed elements, the concentration of the internal standard has to be known. The isotope Si29 was used for internal standardization. Concentrations for major elements, including silica, are calculated assuming that the sum of their concentrations in weight percent in glass is equal to 100 % (Gratuze, 1999).

Fully quantitative analyses are possible by using external standards. To prevent matrix effects, the composition of standards has to be as close as possible to that of the samples. Two different series of standards are used to measure major, minor and trace elements. The first series of external standards are standard reference materials (SRM) manufactured by NIST: SRM 610 and SRM 612. Both of these standards are soda-lime-silica glass doped with trace elements in the range of 500 ppm (SRM 610) and 50 ppm (SRM 612). Certified values are available for a very limited number of elements. Concentrations from Pearce *et al.* (1997) will be used for the other elements. The second series of standards were manufactured by Corning. Glass B and D are glasses that match compositions of ancient glass (Brill, 1999, vol. 2, p. 544).
The detection limits range from 10 ppb to 1 ppm for most of the elements. Accuracy ranges from 5 to 10 % depending on the elements and their concentrations. A more

detailed account of the performances of this technique can be found in Dussubieux et al. 2009.

Results

Seventy-one artifacts were submitted for LA-ICP-MS analysis and 88 compositions were determined (see Table 1). The different colored glasses of polychrome objects were analyzed separately. At two exceptions (samples IF052 and IF071), the samples belong to two main glass compositions that will be described below.

Compositions

Glass samples are characterized by high alumina concentrations (13 +/- 2 %); however constituents such as magnesia and lime have concentrations varying in a wide range. Soda and potash concentrations vary also quite significantly. A group of glass (n= 59) is characterized by very low magnesia (0.06 +/- 0.02 %) and high lime (15 +/- 2 %) concentrations. The other group of glass (n=27) has higher magnesia (0.9 +/- 0.2 %) and lower lime (3.3 +/-1.4 %) concentrations (Figure 1). This second group of glass has also higher soda, potash and iron concentrations compared to the other one.

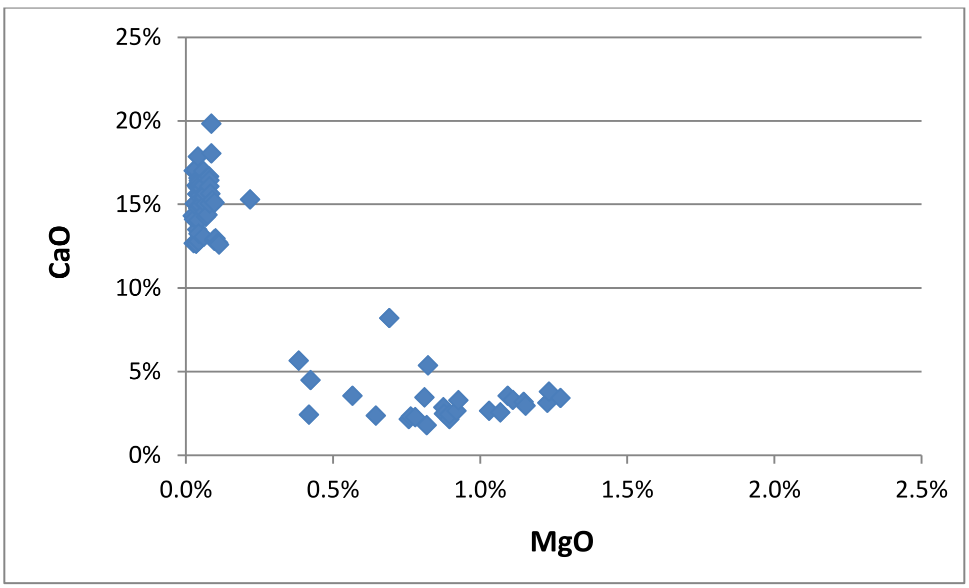

Figure 1. Bi-plot representing MgO and CaO concentrations in the glass samples from Igbo Olokun.

Table 2 presents the averages and the standard deviations for these two glass groups that will be called HLHA or high lime-high alumina (Lankton et al. 2006) glass and LLHA or low lime-high alumina glass.

Other elements are present in different concentrations in the two glasses: copper is systematically present in higher quantities in the LLHA group (0.4 +/-0.1 %) compared to the HLHA group (0.02 +/-0.01 %). The colors of the glass in those two groups of glass are very different with opaque red, opaque yellow, white, black and dark brown glass for the LLHA group and different shades of transparent green and transparent blue, colorless or clear for the HLHA glass. Both glasses are often combined on a single artifact with the HLHA glass constituting the core of the bead and the LLHA glass being used as an outer layer or decorations.

	Average HLHA	**SD**	**Average LLHA**	**SD**
SiO_2	62.32%	1.9%	68.70%	2.6%
Na_2O	3.88%	1.2%	6.47%	1.2%
MgO	0.06%	0.03%	0.88%	0.2%
Al_2O_3	13.5%	1.0%	12.4%	2.4%
K_2O	3.81%	2.1%	5.14%	2.2%
CaO	15.17%	1.5%	3.27%	1.4%
Fe_2O_3	0.55%	0.3%	2.19%	1.1%

Table 2. Average concentrations with standard deviations for the HLHA and LLHA glass groups.

As mentioned above, two samples, IF052 and IF071, have compositions that are significantly different from the two compositions described above.

IF051 is a piece of glass that was attached to a crucible. It is characterized by very high alumina concentrations (~28 %). Other element concentrations fall in the range of the composition of the HLHA glass. Could this high alumina concentration be caused by contamination from the crucible that has a high alumina fabric?

IF071 is a piece of partially vitrified material with a relatively high alumina concentration (~10%) but with a very low soda content (<1 %). Other constituents present in significant quantities are MgO (~2 %), K_2O (~4 %), CaO ~8 %.

Coloring and opacifying agents

More than half of the HLHA glass samples contain significant quantities of cobalt to produce different shades of dark blue glass. Higher concentrations of cobalt are connected to higher concentrations of manganese (Figure 2) but also to higher concentrations of other trace elements such as lithium, vanadium, nickel, copper…etc.

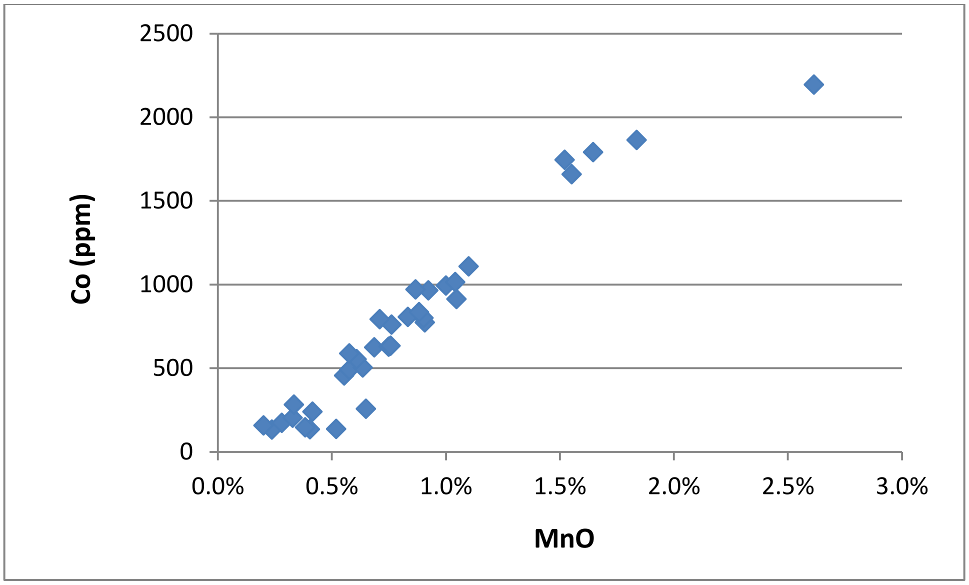

Figure 2. Bi-plot representing the MnO and Co concentrations in the HLHA dark blue glass samples.

Other colors in the HLHA glass group are: translucent or transparent pale blue, emerald green, greenish, red or colorless (indicated also as clear). Aside from manganese and iron, that can be natural constituents of the sand but also added in purpose to impart a specific color to the glass, no other coloring element was identified in those colored glass samples. Figure 3 shows the concentrations of iron and manganese in the HLHA glass samples not colored with cobalt.

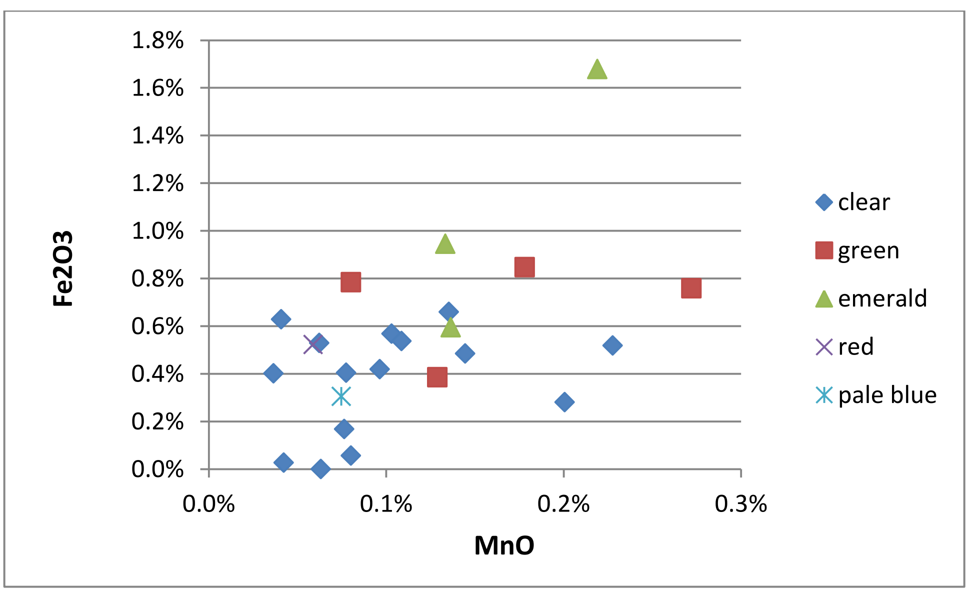

Figure 3. Bi-plot representing the MnO and Fe_2O_3 concentrations in the HLHA translucent or transparent pale blue, emerald green, greenish, red or colorless glass samples.

This figure shows that the concentrations of manganese and iron can be quite similar in greenish, emerald or colorless glass. In the other hand, the concentrations of iron and manganese vary significantly in the colorless glass. It does not seem that any specific coloring recipe was developed to achieve a specific color. Changes in the glass melting atmosphere might have played a major role in producing the different colors, producing different iron and manganese oxidation states.

In the LLHA glass group, the range of colors is very different with a majority of opaque glass: red, yellow and white. Some samples are not totally opaque, but very dark. When a light is shined through those objects they appear mostly brown. In the LLHA glass, manganese is low (<0.1 %) and therefore might not have been added intentionally to modify the color of the glass. Aside from iron and copper, no other element that could have been involved in coloring/opacifying of the glass is present (Figure 4).

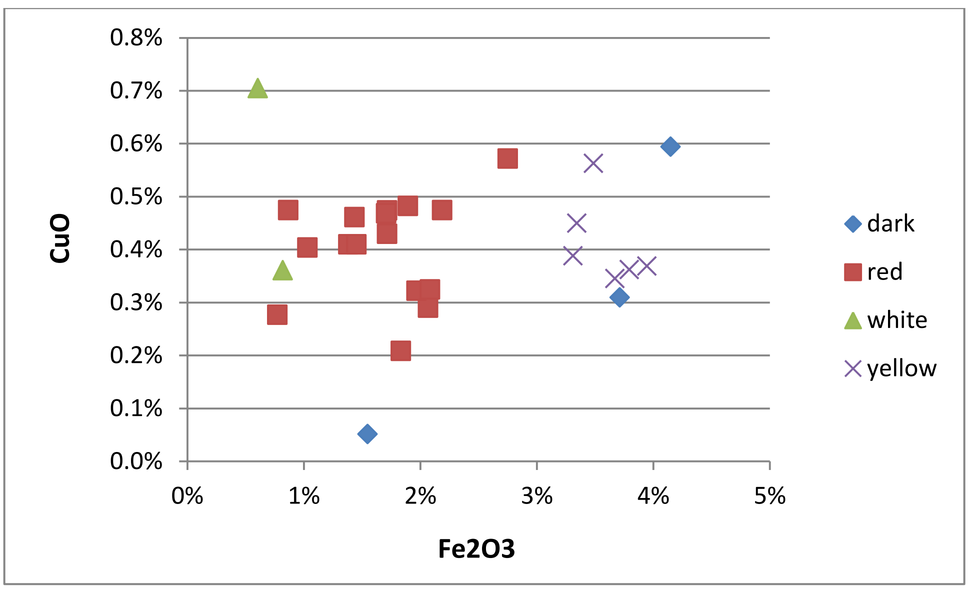

Figure 4. Bi-plot representing the Fe_2O_3 and CuO concentrations in the LLHA dark, opaque red, white and yellow glass samples.

Copper is 0.2 % or more in all the LLHA samples at one exception. Indeed, IF038B only contains 0.05% of copper oxide. White glass samples seem to have lower iron oxide concentrations than average. Yellow and dark glasses have the highest iron concentrations. Different recipes were obviously used to achieve different coloring effects.

Discussion

Comparison with data from the literature

This study can be compared to the work of three other researchers that published chemical data on material from Nigeria.

Davison, Giauque and Clark (1971) and Davison (1972) analyzed glass material from the Ife region using X-Ray Fluorescence (XRF) and Instrumental Neutron Activation Analysis (INAA). The XRF data (Davison, Giauque and Clark, 1971) are extremely difficult to compare to our own data as they comprise a very small number of elements, none of them being major elements, making impossible any recipe reconstruction. INAA results (Davison, 1972) indicate high alumina and high lime concentrations in the glass samples bearing a strong resemblance with the composition of the HLHA group. Almost all samples contain significant concentrations of cobalt. The presence of this element is correlated to the presence of manganese as observed in the present study. Davison did not believe that a local production for this glass was possible but instead, proposed local reworking of glass of European manufacture.

Lankton et al. (2006) published data more readily comparable to our own data. Scanning Electron Microscopy – Energy Dispersive Spectroscopy (SEM-EDS) and XRF was used on fragments of glass-working crucibles and on drawn glass beads from Olokun Grove as well as on ritual glass objects called *aje ileke,* purchased more recently by one of the authors. Lankton et al. (2006) identified different glass types and among them the HLHA glass. No LLHA glass appear in this publication quite likely due to the color range represented in this study that did not comprise any opaque red, yellow, white and dark glasses. The provenance of the HLHA glass is discussed in this article and after a review of the different possibilities, the authors propose a local production for that type of glass due to the high density of HLHA glass in this region and the absence of large quantities of this glass elsewhere. However, the recipe for the HLHA glass remains unknown.

Brill (1999) published HLHA and LLHA compositions from the site of Igbo Ukwu and as in our study, color-specific compositions appear with HLHA glass being mostly transparent or translucent greenish, blue or colorless and the LLHA glass being opaque red or ruby.

Glass recipes

If it seems established that the HLHA glass and quite likely the LLHA glass were locally made, the question of the recipe has not been fully elucidated. Freestone (2006) discussed possible recipes for the HLHA glass type. This author excludes the use of plant ash as a possible source for the lime in that glass as it also contains very little magnesia, a constituent usually present in significant quantities in that type of flux. In his opinion, the use of a rather pure lime source such as limestone, marble or shell is more likely. That kind of flux mixed with sand containing alkali feldspar minerals could explain the composition of the HLHA glass (Freestone, 2006).

The recipe for the LLHA glass is slightly different. Similar alumina concentration in this glass and in the HLHA glass could suggest the use of a same type of sand. The LLHA glass contains more soda and more potash than the HLHA glass and less lime suggesting the substitution (partial or total) of the high lime ingredient by a different ingredient containing soda, magnesia and potash.

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Appendix D.3: Composition of Ile-Ife glass beads analyzed for this study by methods of analysis.

Sample	Color	Method	SiO_2	Na_2O	MgO	Al_2O_3	P_2O_3	Cl	K_2O	CaO	MnO	Fe_2O_3	CuO	SnO_2	PbO_2
HLHA (high CaO, high Al2O3)															
IF0001	Blue-Dichroic	LA-ICP-MS	62.14%	2.45%	0.03%	13.91%	0.16%	0.04%	7.70%	12.64%	0.42%	0.47%	0.01%	0.00%	0.01%
IF0002	Blue	LA-ICP-MS	62.79%	3.45%	0.05%	13.16%	0.10%	0.00%	3.48%	15.34%	0.87%	0.69%	0.02%	0.00%	0.00%
IF0003	Blue	LA-ICP-MS	58.63%	3.57%	0.05%	14.44%	0.18%	0.00%	5.29%	16.33%	0.92%	0.50%	0.02%	0.00%	0.00%
IF0004	Blue	LA-ICP-MS	60.07%	2.24%	0.02%	14.43%	0.13%	0.00%	7.72%	14.30%	0.56%	0.48%	0.01%	0.00%	0.01%
IF0005	Blue	LA-ICP-MS	62.12%	2.88%	0.06%	12.87%	0.08%	0.00%	3.60%	16.04%	1.52%	0.72%	0.03%	0.00%	0.00%
IF0006	Blue	LA-ICP-MS	63.63%	5.07%	0.09%	13.37%	0.14%	0.00%	1.09%	15.25%	0.69%	0.60%	0.01%	0.00%	0.00%
IF0007	Blue-Dichroic	LA-ICP-MS	63.02%	3.08%	0.04%	11.85%	0.10%	0.04%	5.04%	16.42%	0.07%	0.31%	0.00%	0.00%	0.00%
IF0008	Blue	LA-ICP-MS	65.65%	4.68%	0.08%	12.01%	0.13%	0.00%	0.82%	15.04%	1.00%	0.51%	0.02%	0.00%	0.00%
IF0009	Blue	LA-ICP-MS	64.70%	4.91%	0.05%	12.61%	0.10%	0.00%	1.36%	14.93%	0.71%	0.59%	0.01%	0.00%	0.00%
IF0010	Green	LA-ICP-MS	60.35%	5.95%	0.06%	14.22%	0.16%	0.00%	1.29%	16.99%	0.65%	0.29%	0.02%	0.00%	0.00%
IF0011	Blue	LA-ICP-MS	63.04%	4.34%	0.07%	12.77%	0.10%	0.00%	2.53%	15.63%	0.83%	0.62%	0.02%	0.00%	0.00%
IF0012	Blue	LA-ICP-MS	61.42%	4.48%	0.05%	13.73%	0.09%	0.00%	2.92%	15.65%	0.91%	0.67%	0.02%	0.00%	0.00%
IF0013	Pale blue	LA-ICP-MS	58.70%	1.72%	0.07%	15.75%	0.11%	0.00%	8.54%	14.26%	0.38%	0.41%	0.01%	0.00%	0.01%
IF0014	Clear	LA-ICP-MS	61.40%	2.56%	0.04%	13.64%	0.16%	0.00%	7.31%	14.02%	0.33%	0.50%	0.01%	0.00%	0.00%
IF0015	Pale blue	LA-ICP-MS	64.97%	3.20%	0.09%	10.96%	0.15%	0.06%	1.50%	18.04%	0.58%	0.41%	0.01%	0.00%	0.00%
IF0016	Blue	LA-ICP-MS	63.78%	4.27%	0.06%	12.69%	0.13%	0.04%	1.25%	16.12%	1.05%	0.54%	0.03%	0.00%	0.00%
IF0017	Blue	LA-ICP-MS	63.02%	3.53%	0.07%	13.63%	0.11%	0.04%	3.34%	14.54%	1.04%	0.59%	0.03%	0.00%	0.00%
IF0018	Blue	LA-ICP-MS	63.92%	4.78%	0.07%	12.20%	0.17%	0.08%	0.74%	16.57%	0.88%	0.51%	0.02%	0.00%	0.00%
IF0019	Blue	LA-ICP-MS	60.63%	3.37%	0.05%	13.35%	0.14%	0.03%	3.70%	16.26%	1.84%	0.52%	0.03%	0.00%	0.00%
IF0020	Blue	LA-ICP-MS	62.23%	5.07%	0.05%	13.58%	0.13%	0.03%	1.19%	16.19%	0.90%	0.54%	0.03%	0.00%	0.00%

Note: Values of all the trace elements were measured in ppm. * = Color in stripe(s) on the bead, # = color in coating around the bead surface covering the core, and + = partially corroded.

Appendix D.3 (Cont.): Composition of Ile-Ife glass beads analyzed for this study by methods of analysis.

Sample	Color	Method	SiO2	Na2O	MgO	Al2O3	P2O3	Cl	K2O	CaO	MnO	Fe2O3	CuO	SnO2	PbO2
IF0025	Red	LA-ICP-MS	64.13%	5.03%	0.10%	14.02%	0.15%	0.00%	3.00%	12.95%	0.06%	0.52%	0.02%	0.00%	0.00%
IF0026	Clear	LA-ICP-MS	62.24%	4.42%	0.04%	12.87%	0.10%	0.00%	3.22%	16.56%	0.10%	0.42%	0.00%	0.00%	0.01%
IF0028	Clear	LA-ICP-MS	66.34%	4.08%	0.04%	12.50%	0.21%	0.08%	3.57%	12.64%	0.20%	0.28%	0.04%	0.00%	0.00%
IF0029	Clear	LA-ICP-MS	60.79%	5.85%	0.04%	13.11%	0.31%	0.07%	1.15%	17.85%	0.14%	0.66%	0.00%	0.00%	0.00%
IF0030	Clear	LA-ICP-MS	63.60%	3.91%	0.03%	12.59%	0.13%	0.00%	5.57%	14.09%	0.06%	0.00%	0.00%	0.00%	0.01%
IF0031	Clear	LA-ICP-MS	63.10%	3.48%	0.04%	12.81%	0.10%	0.00%	6.38%	13.99%	0.04%	0.03%	0.00%	0.00%	0.01%
IF0032	Clear	LA-ICP-MS	62.23%	6.44%	0.08%	13.34%	0.16%	0.00%	0.84%	16.67%	0.08%	0.17%	0.00%	0.00%	0.00%
IF0033	Clear	LA-ICP-MS	62.85%	4.59%	0.04%	13.49%	0.13%	0.06%	4.87%	13.48%	0.04%	0.40%	0.02%	0.00%	0.01%
IF0034	Clear	LA-ICP-MS	62.41%	6.19%	0.08%	13.34%	0.16%	0.00%	0.88%	16.44%	0.08%	0.40%	0.00%	0.00%	0.00%
IF0036	Clear	LA-ICP-MS	56.86%	5.77%	0.09%	14.84%	0.48%	0.01%	1.44%	19.82%	0.10%	0.57%	0.00%	0.00%	0.00%
IF0037	Blue	LA-ICP-MS	62.18%	2.78%	0.07%	12.94%	0.22%	0.07%	5.58%	15.02%	0.61%	0.47%	0.02%	0.00%	0.00%
IF0038	Clear	LA-ICP-MS	64.64%	3.08%	0.04%	12.76%	0.13%	0.03%	3.50%	14.76%	0.20%	0.83%	0.01%	0.00%	0.00%
IF0039	Clear	LA-ICP-MS	59.96%	2.87%	0.06%	14.60%	0.16%	0.07%	4.97%	15.68%	0.76%	0.75%	0.04%	0.00%	0.01%
IF0039	White*	LA-ICP-MS	60.44%	2.76%	0.06%	14.42%	0.16%	0.07%	5.00%	15.41%	0.75%	0.79%	0.04%	0.00%	0.01%
IF0043	Green	LA-ICP-MS	62.77%	3.74%	0.10%	12.96%	0.17%	0.00%	3.22%	15.10%	0.22%	1.68%	0.01%	0.00%	0.00%
IF0044B	Blue	LA-ICP-MS	59.08%	2.01%	0.06%	14.76%	0.18%	0.05%	6.60%	15.92%	0.64%	0.65%	0.01%	0.00%	0.00%
IF0045	Blue	LA-ICP-MS	62.92%	3.20%	0.05%	13.06%	0.13%	0.06%	3.48%	15.52%	0.76%	0.74%	0.01%	0.00%	0.00%
IF0046	Green	LA-ICP-MS	60.56%	5.76%	0.03%	14.06%	0.21%	0.00%	1.25%	17.07%	0.18%	0.85%	0.00%	0.00%	0.00%
IF0047	Blue	LA-ICP-MS	61.39%	4.24%	0.07%	14.76%	0.17%	0.00%	2.77%	14.37%	1.55%	0.55%	0.03%	0.00%	0.00%
IF0048	Clear	LA-ICP-MS	65.70%	5.53%	0.03%	13.09%	0.12%	0.09%	1.96%	12.66%	0.23%	0.52%	0.03%	0.00%	0.00%
IF0049	Blue	LA-ICP-MS	63.34%	4.48%	0.04%	14.41%	0.10%	0.00%	3.82%	12.77%	0.58%	0.40%	0.01%	0.00%	0.00%
IF0050	Green	LA-ICP-MS	62.95%	3.54%	0.06%	13.17%	0.11%	0.00%	3.31%	15.09%	0.33%	1.40%	0.00%	0.00%	0.00%
IF0051	Clear	LA-ICP-MS	61.53%	5.10%	0.03%	13.02%	0.27%	0.00%	2.35%	17.01%	0.14%	0.49%	0.02%	0.00%	0.00%

Note: Values of all the trace elements were measured in ppm. * = Color in stripe(s) on the bead, # = color in coating around the bead surface covering the core, and + = partially corroded.

Appendix D.3 (Cont.): Composition of Ile-Ife glass beads analyzed for this study by methods of analysis.

Sample	Color	Method	SiO2	Na2O	MgO	Al2O3	P2O3	Cl	K2O	CaO	MnO	Fe2O3	CuO	SnO2	PbO2
IF0069	Clear	LA-ICP-MS	60.19%	2.98%	0.06%	17.09%	0.08%	0.00%	3.63%	15.27%	0.04%	0.63%	0.02%	0.00%	0.00%
IF0070	Clear	LA-ICP-MS	64.55%	4.49%	0.06%	13.17%	0.10%	0.00%	3.98%	13.05%	0.06%	0.53%	0.00%	0.00%	0.01%
Ife A1	Clear	SEM	58.74%	6.00%	0.00%	15.75%			6.17%	11.05%	1.30%	0.00%			
Ife A2	Pale blue	SEM	53.31%	2.32%	0.00%	14.47%			7.00%	16.76%	1.24%	4.96%			
Ife A3	Blue	SEM	56.24%	3.38%	0.00%	17.12%			4.18%	16.82%	2.26%	0.00%			
Ife A4	Blue	SEM	57.40%	3.67%	0.00%	13.71%			3.83%	19.22%	2.18%	0.00%			
Ife A5	Blue	SEM	54.81%	4.37%	0.00%	12.46%			2.04%	22.14%	2.19%	0.00%			
Ife A6	Blue	SEM	55.24%	3.98%	0.00%	15.60%			4.38%	16.49%	0.45%	3.86%			
Ife A7	Blue	SEM	53.27%	5.23%	0.00%	11.96%			1.96%	21.73%	1.53%	4.32%			
Ife B13	Clear	SEM	59.09%	4.17%	0.00%	13.81%			3.53%	17.58%	0.00%	1.83%			
Ife A8	Clear	SEM	61.93%	6.01%	0.00%	12.98%			1.20%	17.57%	0.31%	0.00%			
Ife B11	Clear	SEM	60.10%	6.60%	0.14%	19.74%			2.26%	9.75%	0.00%	1.41%			
IF0083A+	White	SEM/EDS	60.37%	1.85%	0.00%	14.03%	0.16%	0.01%	9.13%	13.72%	0.41%	0.27%			
IF0083B+	White	SEM/EDS	62.87%	3.50%	0.07%	15.59%	0.96%	0.01%	2.74%	13.25%	0.11%	0.79%			
IF0084+	White	SEM/EDS	61.07%	1.98%	0.01%	12.70%	0.12%	0.01%	7.97%	15.47%	0.29%	0.37%			
LLLA (low CaO, low Al2O3)															
IF0039	Black	LA-ICP-MS	75.38%	4.93%	1.09%	4.33%	0.33%	0.18%	5.29%	3.55%	0.06%	4.15%	0.59%	0.01%	0.07%
IF0048	Yeloow*	LA-ICP-MS	74.70%	5.87%	0.82%	6.19%	0.40%	0.17%	2.51%	5.37%	0.09%	3.34%	0.45%	0.00%	0.05%
IF0048	Red*	LA-ICP-MS	72.68%	5.95%	0.81%	8.82%	0.33%	0.22%	4.25%	3.44%	0.06%	2.75%	0.57%	0.01%	0.05%

Note: Values of all the trace elements were measured in ppm. * = Color in stripe(s) on the bead, # = color in coating around the bead surface covering the core, and + = partially corroded.

Appendix D.3 (Cont.): Composition of Ile-Ife glass beads analyzed for this study by methods of analysis.

Sample	Color	Method	SiO2	Na2O	MgO	Al2O3	P2O3	Cl	K2O	CaO	MnO	Fe2O3	CuO	SnO2	PbO2
LLHA (low CaO, high Al2O3)															
IF0037	White*	LA-ICP-MS	63.10%	6.66%	0.69%	12.58%	0.31%	0.29%	6.68%	8.20%	0.09%	0.60%	0.70%	0.01%	0.05%
IF0026	Red*	LA-ICP-MS	67.95%	7.49%	1.16%	13.03%	0.26%	0.28%	4.62%	2.94%	0.04%	1.71%	0.47%	0.00%	0.02%
IF0027	Red	LA-ICP-MS	70.12%	8.05%	1.07%	12.23%	0.26%	0.00%	3.74%	2.55%	0.03%	1.45%	0.41%	0.01%	0.04%
IF0028	Red#	LA-ICP-MS	66.18%	6.01%	0.78%	14.53%	0.29%	0.18%	7.31%	2.27%	0.03%	2.07%	0.29%	0.00%	0.03%
IF0029	Red#	LA-ICP-MS	66.81%	6.12%	0.42%	13.15%	0.23%	0.24%	8.55%	2.41%	0.04%	1.38%	0.41%	0.00%	0.20%
IF0035	Yellow	LA-ICP-MS	68.24%	8.40%	0.88%	12.96%	0.27%	0.00%	2.47%	2.47%	0.04%	3.79%	0.36%	0.01%	0.05%
IF0036	Red#	LA-ICP-MS	68.35%	8.12%	0.93%	14.62%	0.29%	0.17%	1.46%	3.26%	0.06%	2.19%	0.47%	0.01%	0.03%
IF0038	Black*	LA-ICP-MS	69.60%	4.60%	0.38%	12.69%	0.19%	0.10%	5.02%	5.64%	0.08%	1.55%	0.05%	0.00%	0.07%
IF0038	White*	LA-ICP-MS	67.18%	6.07%	0.42%	14.97%	0.26%	0.18%	5.03%	4.48%	0.04%	0.82%	0.36%	0.02%	0.13%
IF0039	Red*	LA-ICP-MS	68.47%	5.47%	0.82%	12.41%	0.26%	0.19%	8.13%	1.79%	0.03%	1.89%	0.48%	0.00%	0.02%
IF0040	Yellow	LA-ICP-MS	68.72%	7.92%	1.03%	11.74%	0.25%	0.00%	3.20%	2.64%	0.04%	3.94%	0.37%	0.01%	0.06%
IF0041	Yellow	LA-ICP-MS	69.40%	7.39%	0.92%	12.25%	0.28%	0.00%	3.27%	2.65%	0.06%	3.31%	0.39%	0.01%	0.04%
IF0042	Yellow	LA-ICP-MS	68.99%	6.92%	0.90%	12.38%	0.28%	0.00%	4.17%	2.15%	0.05%	3.67%	0.34%	0.01%	0.06%
IF0044	Red*	LA-ICP-MS	66.46%	3.82%	0.76%	13.92%	0.24%	0.22%	10.92%	2.15%	0.04%	1.03%	0.40%	0.00%	0.02%
IF0045	White*	LA-ICP-MS	67.51%	7.15%	1.23%	11.37%	0.36%	0.16%	4.25%	3.79%	0.06%	3.49%	0.56%	0.01%	0.03%
IF0051	Red#	LA-ICP-MS	66.91%	7.55%	0.57%	13.40%	0.30%	0.00%	5.78%	3.54%	0.03%	1.43%	0.46%	0.00%	0.02%
IF0069	Red#	LA-ICP-MS	68.01%	6.11%	1.15%	13.37%	0.28%	0.00%	5.72%	3.17%	0.04%	1.83%	0.21%	0.01%	0.06%
Ife B9	Yellow	SEM	55.01%	6.44%	1.72%	13.54%			3.90%	3.98%	0.00%	10.73%			
Ife B10	Yellow	SEM	52.76%	4.38%	1.77%	18.76%			3.32%	4.82%	0.00%	14.18%			
Ife B12	Red#	SEM	63.39%	7.02%	1.18%	14.47%			6.08%	3.17%	0.00%	4.68%			

Appendix D. 4: Compositional groups identified for Ile-Ife glass beads by different researchers

Davison 1972	**Lankton *et al* 2006**	**Ige *et al* (Under Review)**	**Brill analyzed for Ige**	**Babalola This Work**
Class I: high lime, high alumina	**High lime, high alumina**	**High lime, high alumina**	**Low lime, high alumina**	**High lime, high alumina**
CaO (11-18wt%)	CaO & Al_2O_3 15-17wt%	CaO (10-15wt%)	CaO (0.9-3wt%)	CaO (10-22wt%)
Al_2O_3 (10-17wt%)	Na_2O (5-6.8wt%)	Al_2O_3 (12-19wt%)	Al_2O_3 (16wt%)	Al_2O_3 (10-19wt%)
Na_2O (2-4wt%)	K_2O (2.6-5.6wt%)	Na_2O (1-5wt%)	Na_2O (2-6wt%)	Na_2O (1-6wt%)
K_2O (5-9wt%)	Fe_2O_3 (<1wt%)	K_2O (2-7wt%)	K_2O (3-9wt%)	K_2O (1-9wt%)
Fe_2O_3 (<0.5wt%; upto 1.5wt% in black)	MnO (<1wt%)	Fe_2O_3 (0.8-2wt%)	Fe_2O_3 (0.8-5wt%)	Fe_2O_3 (0-1.6wt%)
MnO (0.1-0.7wt%)	MgO (0.1wt% - nd)	MnO (0.1-0.8wt%)	MgO (0-0.3wt%)	MnO (0-2wt%)
Co (0.02-0.1wt%)		MgO (0.1-0.9wt%-nd)		MgO (0-0.1wt%)
		Rb (60-396ppm)		Rb (30-625ppm)
		Sr (180-339ppm)		Sr (200-400ppm)
Class II: Soda-lime glass	**Soda-lime glass**	**Low lime, high alumina**	**Soda-lime glass**	**Low lime, high alumina**
CaO (not listed)	CaO (6-8wt%)	CaO (2-2.5wt%)	CaO (4-9wt%)	CaO (1-8wt%)
Al_2O_3 (2-8wt%)	Al_2O_3 (<1wt%)	Al_2O_3 (12-15wt%)	Al_2O_3 (0.6-4wt%)	Al_2O_3 (12-15wt%)
K_2O (not listed)	Na_2O (15-16wt%)	Na_2O (5-7wt%)	Na_2O (13-20wt%)	Na_2O (4-8wt%)
Na_2O (9-15wt%)	K_2O (<1wt%)	K_2O (2.8-8wt%)	K_2O (0.3-2.7wt%)	K_2O (2-10wt%)
Fe_2O_3 (0.5-1.7wt%)	Fe_2O_3 (0.1wt%)	Fe_2O_3 (1-6wt%)	Fe_2O_3 (0.5-9.8wt%)	Fe_2O_3 (1-3.9wt%)
MnO (300-6900ppm)	MnO (0.02wt%-nd)	MnO (0.0.2-0.04wt%)	MgO (0.1-0.9wt%)	MnO (0.03-0.09wt%)
Co (4-99ppm)		MgO (0.6-1wt%-nd)		MgO (0.1-1wt%-nd)
		Rb (90-641ppm)		Rb (60-738ppm)
		Sr (100-157ppm)		Sr (100-340ppm)

Appendix D. 4 (Cont.): Compositional groups identified for Ile-Ife glass beads by different researchers

Davison 1972	**Lankton et al 2006**	Ige et al (Under Review)	Brill analyzed for Ige	**Babalola This Work**
Class III: Miscellaneous	**Mixed high lime and soda lime**			**Low lime, low alumina**
Low lime (<1wt%), high alumina (≥10wt%)	CaO (5-12wt%)			CaO (3-5wt%)
K2O (5wt%)	Al2O3 (1-7wt%)			Al2O3 (4-9wt%)
Na2O (6wt%)	Na2O (12-17wt%)			Na2O (4-6wt%)
Fe2O3 (1wt%)	K2O (0.8-2.7wt%)			K2O (2-5wt%)
	Fe2O3 (1-1.6wt%)			Fe2O3 (2-4wt%)
High lime (9-17wt%), low lime (<4wt%)	MgO (0.4-1wt%)			MnO (0.06-0.09wt%)
K2O (<3wt%)	MnO (0.1-1wt%)			MgO (0.8-1wt%)
				Rb (100-300ppm)
				Sr (200-280ppm)
	High lime, low alumina			
	CaO (20-24wt%)			
	Al2O3 (3.5.8wt%)			
	Na2O (1-5wt%)			
	K2O (0.6-1wt%)			
	Fe2O3 (1-2.8wt%)			
	MgO (2-3wt%)			
	MnO (0.1wt%)			
	Mixed alkali			
	CaO (4.8wt%)			
	Al2O3 (8wt%)			
	Na2O (9wt%)			
	K2O (3.8wt%)			
	Fe2O3 (3.7wt%)			
	MgO (1.6wt%), MnO (4.7wt%)			

APPENDIX E

Appendix E.1: Data for recorded crucible fragments by excavation unit and level

Site	Unit	Level	Weight (g)	Thickness (mm)	Part of vessel	IG	OG	GCI	GCO	IS	OS	PC	<4cm (count)
IO	IO-A	1	62	26.29	2	1	1	1	2	1	2	1	
IO	IO-A	1	124	33.88	2	1	1	6	1	1	2	1	
IO	IO-A	1	55	47.17	2	1	1	1	1	1	2	1	
IO	IO-A	1	36	11.7	2	1	2	6	0	1	1	1	
IO	IO-A	1	70	13.61	2	1	2	6	0	1	2	1	
IO	IO-A	1	35	18.08	1	1	2	4	0	1	2	1	
IO	IO-A	1	56	21.2	2	1	2	7	0	1	1	1	
IO	IO-A	1	28	23.25	2	1	2	1	0	2	1	1	6
IO	IO-A	2	44	24.02	2	1	1	2	2	1	2	1	
IO	IO-A	2	19	21.31	2	1	2	1	0	2	2	1	
IO	IO-A	2	15	15.44	2	2	2	0	0	2	1	1	
IO	IO-A	2	85	17.14	1	2	2	0	0	1	2	1	
IO	IO-A	3	15	16.16	2	1	1	2	2	1	1	1	
IO	IO-A	3	24	17.71	2	1	1	1	2	2	1	1	
IO	IO-A	3	9	18.6	2	1	1	1	2	2	1	1	
IO	IO-A	3	72	19.39	2	1	1	1	6	1	2	1	
IO	IO-A	3	220	19.42	1	1	1	1	2	1	2	1	
IO	IO-A	3	52	22.74	2	1	1	2	2	2	1	1	
IO	IO-A	3	97	23.44	2	1	1	6	1	1	2	1	
IO	IO-A	3	77	27.6	2	1	1	1	2	2	2	1	
IO	IO-A	3	46	31.04	2	1	1	1	2	1	2	1	
IO	IO-A	3	26	14.08	2	1	2	6	0	1	1	1	
IO	IO-A	3	21	15.82	2	1	2	1	0	2	1	1	
IO	IO-A	3	56	21.68	2	1	2	1	0	1	2	1	
IO	IO-A	3	22	21.72	2	1	2	2	0	1	2	1	
IO	IO-A	3	72	24.73	2	1	2	2	0	1	2	1	
IO	IO-A	3	107	25.43	2	1	2	1	0	2	2	1	
IO	IO-A	3	18	25.68	2	1	2	6	0	2	2	1	
IO	IO-A	3	38	27.46	2	1	2	2	0	1	1	1	
IO	IO-A	3	141	32.64	2	1	2	2	0	2	1	1	
IO	IO-A	3	25	17.88	2	2	1	0	2	1	1	1	
IO	IO-A	3	20	12.67	2	2	2	0	0	1	2	1	
IO	IO-A	3	16	13.95	2	2	2	0	0	1	1	1	2
IO	IO-A	3	31	21.95	2	2	2	0	0	1	2	1	
IO	IO-A	3	101	33.31	2	2	2	0	0	2	1	1	

Note: See table 8.1 for the code description. Sampling Fraction is 100%. Variables: IG (Inside Glass), OG (Outside Glass), GCI (Glass Color Inside), GCO (Glass Color Outside), IS (Inside Surface), OS (Outside Surface), PC (Paste Color)

Appendix E.1 (Cont.): Data for recorded crucible fragments by excavation unit and level

Site	Unit	Level	Weight (g)	Thickness (mm)	Part of vessel	IG	OG	GCI	GCO	IS	OS	PC	<4cm (count)
IO	IO-A	4	263	30.1	2	1	1	2	6	1	2	1	
IO	IO-A	4	36	19.56	2	2	1	0	2	2	1	1	2
IO	IO-B	1	47	20.13	2	1	1	2	6	2	2	1	
IO	IO-B	1	38	18.17	2	1	2	2	0	1	2	1	1
IO	IO-B	2	43	20.27	2	1	1	2	2	2	2	1	
IO	IO-B	2	95	29.37	2	1	1	1	1	1	2	1	
IO	IO-B	2	99	19.69	2	1	2	1	0	2	2	1	
IO	IO-B	2	89	23.13	2	1	2	2	0	2	1	1	
IO	IO-B	2	34	26.13	1	1	2	1	0	1	2	1	1
IO	IO-B	3	30	15.59	2	1	2	2	0	2	1	1	1
IO	IO-B	3	64	31.48	2	1	2	1	0	2	1	1	
IO	IO-B	4	34	11.68	2	1	1	1	2	1	2	1	
IO	IO-B	4	32	15.27	2	1	1	2	2	1	1	1	
IO	IO-B	4	35	18.24	2	1	1	4	2	1	1	1	
IO	IO-B	4	82	19.3	2	1	1	2	2	1	2	1	
IO	IO-B	4	39	21.31	2	1	1	1	2	1	2	1	
IO	IO-B	4	146	34.19	2	1	1	2	6	2	2	1	
IO	IO-B	4	55	41.27	2	1	1	2	2	1	1	1	
IO	IO-B	4	84	16	2	1	2	4	0	1	2	1	
IO	IO-B	4	36	17.14	2	1	2	5	0	1	1	1	
IO	IO-B	4	43	18.51	2	1	2	1	0	1	2	1	
IO	IO-B	4	54	19.09	2	1	2	2	0	2	1	1	
IO	IO-B	4	68	20.02	2	1	2	6	0	1	1	1	
IO	IO-B	4	71	20.1	2	1	2	1	0	2	1	1	
IO	IO-B	4	41	21.13	2	1	2	2	0	1	1	1	
IO	IO-B	4	26	21.2	2	1	2	4	0	1	2	1	
IO	IO-B	4	28	23.22	2	1	2	5	0	1	1	1	
IO	IO-B	4	38	23.47	2	1	2	4	0	1	2	1	
IO	IO-B	4	151	25.13	2	1	2	2	0	1	1	1	
IO	IO-B	4	220	28.92	2	1	2	1	0	1	2	1	
IO	IO-B	4	45	29.77	2	1	2	2	0	2	1	1	
IO	IO-B	4	434	82.02	1	1	2	6	0	2	2	1	
IO	IO-B	4	24	15.13	2	2	1	0	2	1	2	1	27
IO	IO-B	4	66	17.73	2	2	1	0	2	1	2	1	
IO	IO-B	4	28	15.24	2	2	2	0	0	1	1	1	
IO	IO-B	4	26	17.01	2	2	2	0	0	1	2	1	

Note: See table 8.1 for the code description. Sampling Fraction is 100%. Variables: IG (Inside Glass), OG (Outside Glass), GCI (Glass Color Inside), GCO (Glass Color Outside), IS (Inside Surface), OS (Outside Surface), PC (Paste Color)

Appendix E.1 (Cont.): Data for recorded crucible fragments by excavation unit and level

Site	Unit	Level	Weight (g)	Thickness (mm)	Part of vessel	IG	OG	GCI	GCO	IS	OS	PC	<4cm (count)
IO	IO-B	4	38	18.43	2	2	2	0	0	1	1	1	
IO	IO-B	4	37	19.8	1	2	2	0	0	2	1	1	
IO	IO-B	4	35	20.33	2	2	2	0	0	1	1	1	
IO	IO-B	4	90	23.61	2	2	2	0	0	2	2	1	
IO	IO-B	4	59	28.77	2	2	2	0	0	1	1	1	
IO	IO-B	5	29	19.23	1	1	1	6	2	2	1	1	
IO	IO-B	5	28	20.88	1	1	1	1	2	1	2	1	
IO	IO-B	5	46	18.57	2	1	2	1	0	1	1	1	
IO	IO-B	5	56	22.75	1	1	2	2	0	1	2	1	
IO	IO-B	5	80	23.9	2	1	2	2	0	1	1	1	
IO	IO-B	5	33	21.08	2	2	2	0	0	1	2	1	
IO	IO-B	5	39	21.24	2	2	2	0	0	2	1	1	
IO	IO-B	5	55	22.99	2	2	2	0	0	1	1	1	
IO	IO-B	5	31	35.1	2	2	2	0	0	2	1	1	5
IO	IO-B	6	48	32.71	2	1	1	2	2	2	1	1	
IO	IO-B	6	20	16.89	1	1	2	4	0	2	1	1	15
IO	IO-B	6	37	17.48	2	1	2	2	0	1	1	1	
IO	IO-B	6	32	18.6	2	1	2	1	0	2	2	1	
IO	IO-B	6	39	19.79	2	1	2	1	0	2	1	1	
IO	IO-B	6	28	20.57	2	1	2	2	0	1	1	1	
IO	IO-B	6	59	21.5	2	1	2	1	0	1	2	1	
IO	IO-B	6	63	22.36	2	1	2	1	0	1	1	1	
IO	IO-B	6	48	23.45	2	1	2	2	0	1	1	1	
IO	IO-B	6	51	24.39	2	1	2	1	0	1	2	1	
IO	IO-B	6	100	33.15	2	2	1	0	2	2	1	1	
IO	IO-B	6	49	19.64	2	2	2	0	0	1	1	1	
IO	IO-B	6	36	24.23	2	2	2	0	0	1	1	1	
IO	IO-B	6	43	25.3	2	2	2	0	0	1	1	1	
IO	IO-B	7	27	19.26	2	1	1	1	2	2	2	1	
IO	IO-B	7	64	20.51	2	1	1	2	2	1	2	1	
IO	IO-B	7	25	12.76	2	1	2	6	0	1	1	1	15
IO	IO-B	7	48	15.48	2	1	2	2	0	1	2	1	
IO	IO-B	7	31	15.87	2	1	2	4	0	1	1	1	
IO	IO-B	7	25	16.08	2	1	2	2	0	2	1	1	
IO	IO-B	7	50	18.66	2	1	2	1	0	1	2	1	
IO	IO-B	7	34	24.02	2	1	2	5	0	2	1	1	

Note: See table 8.1 for the code description. Sampling Fraction is 100%. Variables: IG (Inside Glass), OG (Outside Glass), GCI (Glass Color Inside), GCO (Glass Color Outside), IS (Inside Surface), OS (Outside Surface), PC (Paste Color)

Appendix E.1 (Cont.): Data for recorded crucible fragments by excavation unit and level

Site	Unit	Level	Weight (g)	Thickness (mm)	Part of vessel	IG	OG	GCI	GCO	IS	OS	PC	<4cm (count)
IO	IO-B	7	56	25.46	2	1	2	2	0	2	1	1	
IO	IO-B	7	31	25.72	2	1	2	2	0	2	1	1	
IO	IO-B	7	239	28.39	2	1	2	1	0	2	2	1	
IO	IO-B	7	121	49.12	2	1	2	2	0	1	2	1	
IO	IO-B	7	74	28.99	2	2	1	0	2	1	1	1	
IO	IO-B	7	24	16.48	2	2	2	0	0	2	1	1	
IO	IO-B	7	54	16.73	2	2	2	0	0	1	1	1	
IO	IO-B	7	61	17.82	2	2	2	0	0	1	1	1	
IO	IO-B	7	94	22.93	2	2	2	0	0	2	1	1	
IO	IO-B	7	39	23.06	2	2	2	0	0	1	1	1	
IO	IO-B	7	103	24.21	2	2	2	0	0	2	2	1	
IO	IO-B	7	44	26.34	2	2	2	0	0	1	1	1	
IO	IO-B	8	44	17.36	2	1	1	6	2	2	1	1	
IO	IO-B	8	100	21.28	1	1	1	1	2	1	2	1	
IO	IO-B	8	23	25.46	2	1	1	1	2	1	1	1	
IO	IO-B	8	64	35.35	2	1	1	1	2	1	1	1	
IO	IO-B	8	473	40.09	3	1	1	6	6	2	2	1	
IO	IO-B	8	34	19.6	2	1	2	2	0	2	1	1	
IO	IO-B	8	40	20.71	2	1	2	1	0	1	1	1	
IO	IO-B	8	47	20.78	2	1	2	8	0	1	2	1	
IO	IO-B	8	111	21.21	2	1	2	1	0	1	2	1	
IO	IO-B	8	43	21.61	2	1	2	2	0	1	1	1	
IO	IO-B	8	45	21.64	2	1	2	2	0	1	2	1	
IO	IO-B	8	58	21.8	2	1	2	2	0	2	2	1	
IO	IO-B	8	50	23.33	2	1	2	1	0	2	2	1	
IO	IO-B	8	72	25.61	2	1	2	5	0	1	1	1	
IO	IO-B	8	111	26.51	2	1	2	2	0	1	2	1	
IO	IO-B	8	66	29.58	2	1	2	6	0	1	2	1	
IO	IO-B	8	55	31.71	2	1	2	2	0	1	1	1	
IO	IO-B	8	86	32.68	2	1	2	2	0	1	1	1	
IO	IO-B	8	111	35.2	2	1	2	6	0	1	1	1	
IO	IO-B	8	19	10.76	2	2	1	0	2	1	1	1	
IO	IO-B	8	19	16.12	2	2	1	0	6	2	2	1	23
IO	IO-B	8	40	19.23	1	2	1	0	2	1	2	1	
IO	IO-B	8	131	53.3	2	2	1	0	2	2	1	1	
IO	IO-B	8	37	20.34	2	2	2	0	0	1	1	1	

Note: See table 8.1 for the code description. Sampling Fraction is 100%. Variables: IG (Inside Glass), OG (Outside Glass), GCI (Glass Color Inside), GCO (Glass Color Outside), IS (Inside Surface), OS (Outside Surface), PC (Paste Color)

Appendix E.1 (Cont.): Data for recorded crucible fragments by excavation unit and level

Site	Unit	Level	Weight (g)	Thickness (mm)	Part of vessel	IG	OG	GCI	GCO	IS	OS	PC	<4cm (count)
IO	IO-B	8	115	26.38	2	2	2	0	0	1	1	1	
IO	IO-B	8	67	26.39	2	2	2	0	0	1	1	1	
IO	IO-B	8	35	31.81	2	2	2	0	0	2	1	1	
IO	IO-B	5	81	33.42	2	1	1	2	2	1	2	1	
IO	IO-B	5	39	22.63	2	1	2	1	0	2	1	1	7
IO	IO-B	5	53	34.28	2	1	2	1	0	1	1	1	
IO	IO-B	5	23	16.42	2	2	1	0	2	1	1	1	
IO	IO-B	5	45	27.41	2	2	1	0	2	1	2	1	
IO	IO-B	5	73	22.1	2	2	2	0	0	1	1	1	
IO	IO-C	1	30	20.13	2	1	1	1	1	1	2	1	
IO	IO-C	1	53	22	2	1	1	1	2	2	2	1	
IO	IO-C	1	29	18.17	2	1	2	2	0	1	2	1	
IO	IO-C	1	41	19.1	2	1	2	1	0	1	2	1	
IO	IO-C	1	38	20.09	2	1	2	1	0	1	2	1	2
IO	IO-C	1	47	21.3	2	1	2	6	0	2	2	1	
IO	IO-C	2	43	20.27	2	1	1	2	2	2	2	1	
IO	IO-C	2	28	25.13	2	1	1	2	2	1	2	1	8
IO	IO-C	2	95	29.37	2	1	1	1	1	1	2	1	
IO	IO-C	2	99	19.69	2	1	2	1	0	2	2	1	
IO	IO-C	2	51	20	2	1	2	2	0	1	1	1	
IO	IO-C	2	40	20.27	2	1	2	6	0	1	1	1	
IO	IO-C	2	89	23.13	2	1	2	2	0	2	1	1	
IO	IO-C	2	34	26.13	2	1	2	1	0	1	2	1	
IO	IO-C	2	26	30.1	2	3	2	1	0	1	2	1	
IO	IO-C	2	35	19.09	2	6	2	6	0	2	2	1	
IO	IO-C	2	29	22.31	2	9	2	2	0	1	1	1	
IO	IO-C	3	15	16.16	2	1	1	2	2	1	1	1	2
IO	IO-C	3	24	17.71	2	1	1	1	2	2	1	1	
IO	IO-C	3	31	18.56	1	1	1	1	1	1	2	1	
IO	IO-C	3	9	18.6	2	1	1	1	2	2	1	1	
IO	IO-C	3	72	19.39	2	1	1	1	6	1	2	1	
IO	IO-C	3	247	21.37	2	1	1	2	2	2	1	1	
IO	IO-C	3	52	22.74	2	1	1	2	2	2	1	1	
IO	IO-C	3	97	23.44	2	1	1	6	1	1	2	1	
IO	IO-C	3	46	31.04	2	1	1	1	2	1	2	1	
IO	IO-C	3	28	35.8	2	1	1	2	2	1	2	1	

Note: See table 8.1 for the code description. Sampling Fraction is 100%. Variables: IG (Inside Glass), OG (Outside Glass), GCI (Glass Color Inside), GCO (Glass Color Outside), IS (Inside Surface), OS (Outside Surface), PC (Paste Color)

Appendix E.1 (Cont.): Data for recorded crucible fragments by excavation unit and level

Site	Unit	Level	Weight (g)	Thickness (mm)	Part of vessel	IG	OG	GCI	GCO	IS	OS	PC	<4cm (count)
IO	IO-C	3	169	56.91	2	1	1	1	1	1	1	1	
IO	IO-C	3	26	14.08	2	1	2	6	0	1	1	1	
IO	IO-C	3	27	14.94	2	1	2	2	0	1	1	1	
IO	IO-C	3	30	15.59	2	1	2	2	0	2	1	1	1
IO	IO-C	3	21	15.82	2	1	2	1	0	2	1	1	
IO	IO-C	7	43	16.81	2	1	2	2	0	1	1	1	
IO	IO-C	7	68	19.17	1	1	2	2	0	1	1	1	
IO	IO-C	7	56	21.68	2	1	2	1	0	1	2	1	
IO	IO-C	7	58	22.7	2	1	2	5	0	1	1	1	1
IO	IO-C	7	72	24.73	2	1	2	2	0	1	2	1	
IO	IO-C	7	50	24.78	2	1	2	1	0	1	1	1	
IO	IO-C	7	94	25.27	2	1	2	2	0	2	1	1	
IO	IO-C	7	68	25.69	2	1	2	2	0	2	2	1	
IO	IO-C	7	38	27.46	2	1	2	2	0	1	1	1	
IO	IO-C	7	35	31.01	2	1	2	4	0	1	1	1	
IO	IO-C	7	64	31.48	2	1	2	1	0	2	1	1	
IO	IO-C	7	87	33.01	2	1	2	2	0	2	2	1	
IO	IO-C	7	105	44.5	2	1	2	2	0	2	1	1	
IO	IO-C	7	25	17.88	2	2	1	0	2	1	1	1	
IO	IO-C	7	43	20.7	2	2	2	0	0	1	2	1	
IO	IO-C	7	31	21.95	2	2	2	0	0	1	2	1	
IO	IO-C	4	34	11.68	2	1	1	1	2	1	2	1	
IO	IO-C	4	32	15.27	2	1	1	2	2	1	1	1	
IO	IO-C	4	39	21.31	2	1	1	1	2	1	2	1	
IO	IO-C	4	81	33.42	2	1	1	2	2	1	2	1	
IO	IO-C	4	55	41.27	2	1	1	2	2	1	1	1	
IO	IO-C	4	36	17.14	2	1	2	5	0	1	1	1	
IO	IO-C	4	54	19.09	2	1	2	2	0	2	1	1	
IO	IO-C	4	26	21.2	2	1	2	4	0	1	2	1	
IO	IO-C	4	39	22.63	2	1	2	1	0	2	1	1	7
IO	IO-C	4	28	23.22	2	1	2	5	0	1	1	1	
IO	IO-C	4	38	23.47	2	1	2	4	0	1	2	1	
IO	IO-C	4	45	29.77	2	1	2	2	0	2	1	1	
IO	IO-C	4	53	34.28	2	1	2	1	0	1	1	1	
IO	IO-C	4	24	15.13	2	2	1	0	2	1	2	1	27
IO	IO-C	4	23	16.42	2	2	1	0	2	1	1	1	

Note: See table 8.1 for the code description. Sampling Fraction is 100%. Variables: IG (Inside Glass), OG (Outside Glass), GCI (Glass Color Inside), GCO (Glass Color Outside), IS (Inside Surface), OS (Outside Surface), PC (Paste Color)

Appendix E.1 (Cont.): Data for recorded crucible fragments by excavation unit and level

Site	Unit	Level	Weight (g)	Thickness (mm)	Part of vessel	IG	OG	GCI	GCO	IS	OS	PC	<4cm (count)
IO	IO-C	4	45	27.41	2	2	1	0	2	1	2	1	
IO	IO-C	4	28	15.24	2	2	2	0	0	1	1	1	
IO	IO-C	4	26	17.01	2	2	2	0	0	1	2	1	
IO	IO-C	4	37	19.8	1	2	2	0	0	2	1	1	
IO	IO-C	4	35	20.33	2	2	2	0	0	1	1	1	
IO	IO-C	4	73	22.1	2	2	2	0	0	1	1	1	
IO	IO-C	5	30	12.56	2	1	1	2	6	1	2	1	
IO	IO-C	5	33	15.82	2	1	1	1	2	2	1	1	
IO	IO-C	5	46	15.85	2	1	1	2	2	1	1	1	
IO	IO-C	5	25	18.99	2	1	1	1	2	1	1	1	
IO	IO-C	5	29	19.23	1	1	1	6	2	2	1	1	
IO	IO-C	5	32	20.15	2	1	1	1	2	1	2	1	
IO	IO-C	5	28	20.88	1	1	1	1	2	1	2	1	
IO	IO-C	5	108	22.96	2	1	1	4	2	1	1	1	
IO	IO-C	5	39	30.05	2	1	1	1	1	1	2	1	
IO	IO-C	5	48	32.71	2	1	1	2	2	2	1	1	
IO	IO-C	5	41	36.3	2	1	1	2	6	2	2	1	
IO	IO-C	5	20	16.89	1	1	2	4	0	2	1	1	12
IO	IO-C	5	37	17.48	2	1	2	2	0	1	1	1	
IO	IO-C	5	37	17.7	2	1	2	1	0	2	1	1	
IO	IO-C	5	46	18.57	2	1	2	1	0	1	1	1	
IO	IO-C	5	32	18.6	2	1	2	1	0	2	2	1	
IO	IO-C	5	41	19.75	2	1	2	1	0	1	1	1	
IO	IO-C	5	39	19.79	2	1	2	1	0	2	1	1	
IO	IO-C	5	33	19.96	2	1	2	1	0	2	2	1	
IO	IO-C	5	28	20.57	2	1	2	2	0	1	1	1	
IO	IO-C	5	34	20.98	2	1	2	1	0	2	1	1	
IO	IO-C	5	59	21.5	2	1	2	1	0	1	2	1	
IO	IO-C	5	63	22.36	2	1	2	1	0	1	1	1	
IO	IO-C	5	56	22.75	1	1	2	2	0	1	2	1	
IO	IO-C	5	39	23.04	2	1	2	1	0	2	1	1	
IO	IO-C	5	48	23.45	2	1	2	2	0	1	1	1	
IO	IO-C	5	80	23.9	2	1	2	2	0	1	1	1	
IO	IO-C	5	51	24.39	2	1	2	1	0	1	2	1	
IO	IO-C	5	52	24.75	2	1	2	1	0	2	2	1	9
IO	IO-C	5	23	24.83	2	1	2	2	0	1	2	1	

Note: See table 8.1 for the code description. Sampling Fraction is 100%. Variables: IG (Inside Glass), OG (Outside Glass), GCI (Glass Color Inside), GCO (Glass Color Outside), IS (Inside Surface), OS (Outside Surface), PC (Paste Color)

Appendix E.1 (Cont.): Data for recorded crucible fragments by excavation unit and level

Site	Unit	Level	Weight (g)	Thickness (mm)	Part of vessel	IG	OG	GCI	GCO	IS	OS	PC	<4cm (count)
IO	IO-C	5	37	28.53	2	1	2	4	0	1	1	1	
IO	IO-C	5	59	31.33	2	1	2	1	0	1	1	1	
IO	IO-C	5	43	20.55	2	2	1	0	2	1	1	1	
IO	IO-C	5	39	21.61	2	2	1	0	2	1	2	1	
IO	IO-C	5	59	25.6	2	2	1	0	2	2	2	1	
IO	IO-C	5	100	33.15	2	2	1	0	2	2	1	1	
IO	IO-C	5	20	12.26	2	2	2	0	0	1	1	1	
IO	IO-C	5	45	15.25	2	2	2	0	0	1	2	1	
IO	IO-C	5	26	18.71	2	2	2	0	0	1	1	1	
IO	IO-C	5	51	19.47	1	2	2	0	0	1	2	1	
IO	IO-C	5	49	19.64	2	2	2	0	0	1	1	1	
IO	IO-C	5	33	21.08	2	2	2	0	0	1	2	1	
IO	IO-C	5	39	21.24	2	2	2	0	0	2	1	1	
IO	IO-C	5	55	22.99	2	2	2	0	0	1	1	1	
IO	IO-C	5	36	24.23	2	2	2	0	0	1	1	1	
IO	IO-C	5	43	25.3	2	2	2	0	0	1	1	1	
IO	IO-C	5	31	35.1	2	2	2	0	0	2	1	1	6
IO	IO-C	6	39	17.24	2	1	1	2	1	2	2	1	
IO	IO-C	6	44	17.36	2	1	1	6	2	2	1	1	
IO	IO-C	6	100	21.28	1	1	1	1	2	1	2	1	
IO	IO-C	6	76	23.27	2	1	1	2	2	2	2	1	
IO	IO-C	6	57	23.47	2	1	1	6	2	2	2	1	
IO	IO-C	6	23	25.46	2	1	1	1	2	1	1	1	
IO	IO-C	6	216	27.46	2	1	1	2	6	2	2	1	
IO	IO-C	6	220	30.62	2	1	1	6	6	2	2	1	
IO	IO-C	6	24	32.08	2	1	1	2	2	2	1	1	
IO	IO-C	6	64	35.35	2	1	1	1	2	1	1	1	
IO	IO-C	6	143	36.36	2	1	1	1	2	2	2	1	
IO	IO-C	6	28	13.07	2	1	2	2	0	2	2	1	19
IO	IO-C	6	87	16.06	2	1	2	1	0	2	1	1	
IO	IO-C	6	22	16.33	2	1	2	2	0	1	1	1	
IO	IO-C	6	84	16.58	2	1	2	2	0	2	1	1	
IO	IO-C	6	73	18.32	2	1	2	5	0	2	1	1	
IO	IO-C	6	75	18.46	1	1	2	1	0	2	2	1	
IO	IO-C	6	51	19.11	2	1	2	6	0	1	2	1	
IO	IO-C	6	45	19.59	2	1	2	1	0	1	1	1	

Note: See table 8.1 for the code description. Sampling Fraction is 100%. Variables: IG (Inside Glass), OG (Outside Glass), GCI (Glass Color Inside), GCO (Glass Color Outside), IS (Inside Surface), OS (Outside Surface), PC (Paste Color)

Appendix E.1 (Cont.): Data for recorded crucible fragments by excavation unit and level

Site	Unit	Level	Weight (g)	Thickness (mm)	Part of vessel	IG	OG	GCI	GCO	IS	OS	PC	<4cm (count)
IO	IO-C	6	34	19.6	2	1	2	2	0	2	1	1	
IO	IO-C	6	88	19.7	2	1	2	5	0	1	1	1	
IO	IO-C	6	214	20.39	2	1	2	1	0	1	1	1	
IO	IO-C	6	40	20.71	2	1	2	1	0	1	1	1	
IO	IO-C	6	34	20.77	2	1	2	2	0	1	1	1	
IO	IO-C	6	47	20.78	2	1	2	8	0	1	2	1	
IO	IO-C	6	31	21.24	2	1	2	6	0	2	2	1	
IO	IO-C	6	43	21.61	2	1	2	2	0	1	1	1	
IO	IO-C	6	45	21.64	2	1	2	2	0	1	2	1	
IO	IO-C	6	70	21.69	2	1	2	1	0	1	1	1	
IO	IO-C	6	58	21.8	2	1	2	2	0	2	2	1	
IO	IO-C	6	55	22.69	1	1	2	2	0	2	1	1	
IO	IO-C	6	48	22.79	2	1	2	2	0	1	2	1	
IO	IO-C	6	53	22.95	2	1	2	1	0	1	2	1	
IO	IO-C	6	52	23	2	1	2	2	0	1	1	1	
IO	IO-C	6	54	23.29	2	1	2	1	0	1	1	1	
IO	IO-C	6	50	23.33	2	1	2	1	0	2	2	1	
IO	IO-C	6	124	25.57	2	1	2	1	0	2	2	1	
IO	IO-C	6	72	25.61	2	1	2	5	0	1	1	1	
IO	IO-C	6	67	25.66	2	1	2	1	0	1	1	1	
IO	IO-C	6	43	26.44	2	1	2	2	0	1	1	1	
IO	IO-C	6	111	26.51	2	1	2	2	0	1	2	1	
IO	IO-C	6	65	26.62	2	1	2	2	0	2	1	1	
IO	IO-C	6	66	29.58	2	1	2	6	0	1	2	1	
IO	IO-C	6	55	31.71	2	1	2	2	0	1	1	1	
IO	IO-C	6	86	32.68	2	1	2	2	0	1	1	1	
IO	IO-C	6	19	10.76	2	2	1	0	2	1	1	1	
IO	IO-C	6	28	14.23	2	2	1	0	2	1	2	1	
IO	IO-C	6	19	16.12	2	2	1	0	6	2	2	1	
IO	IO-C	6	40	19.23	1	2	1	0	2	1	2	1	
IO	IO-C	6	131	53.3	2	2	1	0	2	2	1	1	
IO	IO-C	6	48	17.55	2	2	2	0	0	1	1	1	
IO	IO-C	6	37	20.34	2	2	2	0	0	1	1	1	
IO	IO-C	6	67	26.39	2	2	2	0	0	1	1	1	
IO	IO-C	6	35	31.81	2	2	2	0	0	2	1	1	
IO	IO-D	1	28	20.03	2	2	2	0	0	2	1	1	7

Note: See table 8.1 for the code description. Sampling Fraction is 100%. Variables: IG (Inside Glass), OG (Outside Glass), GCI (Glass Color Inside), GCO (Glass Color Outside), IS (Inside Surface), OS (Outside Surface), PC (Paste Color)

Appendix E.1 (Cont.): Data for recorded crucible fragments by excavation unit and level

Site	Unit	Level	Weight (g)	Thickness (mm)	Part of vessel	IG	OG	GCI	GCO	IS	OS	PC	<4cm (count)
IO	IO-D	2	39	17.24	2	1	1	2	1	2	2	1	
IO	IO-D	2	57	23.47	2	1	1	6	2	2	2	1	
IO	IO-D	2	24	32.08	2	1	1	2	2	2	1	1	
IO	IO-D	2	28	13.07	2	1	2	2	0	2	2	1	18
IO	IO-D	2	22	16.33	2	1	2	2	0	1	1	1	
IO	IO-D	2	75	18.46	1	1	2	1	0	2	2	1	
IO	IO-D	2	51	19.11	2	1	2	6	0	1	2	1	
IO	IO-D	2	45	19.59	2	1	2	1	0	1	1	1	
IO	IO-D	2	88	19.7	2	1	2	5	0	1	1	1	
IO	IO-D	2	31	21.24	2	1	2	6	0	2	2	1	
IO	IO-D	2	70	21.69	2	1	2	1	0	1	1	1	
IO	IO-D	2	55	22.69	1	1	2	2	0	2	1	1	
IO	IO-D	2	48	22.79	2	1	2	2	0	1	2	1	
IO	IO-D	2	53	22.95	2	1	2	1	0	1	2	1	
IO	IO-D	2	52	23	2	1	2	2	0	1	1	1	
IO	IO-D	2	54	23.29	2	1	2	1	0	1	1	1	
IO	IO-D	2	124	25.57	2	1	2	1	0	2	2	1	
IO	IO-D	2	67	25.66	2	1	2	1	0	1	1	1	
IO	IO-D	2	65	26.62	2	1	2	2	0	2	1	1	
IO	IO-D	2	28	14.23	2	2	1	0	2	1	2	1	
IO	IO-D	2	48	17.55	2	2	2	0	0	1	1	1	
IO	IO-D	3	76	23.27	2	1	1	2	2	2	2	1	
IO	IO-D	3	216	27.46	2	1	1	2	6	2	2	1	
IO	IO-D	3	220	30.62	2	1	1	6	6	2	2	1	
IO	IO-D	3	143	36.36	2	1	1	1	2	2	2	1	
IO	IO-D	3	87	16.06	2	1	2	1	0	2	1	1	
IO	IO-D	3	84	16.58	2	1	2	2	0	2	1	1	
IO	IO-D	3	73	18.32	2	1	2	5	0	2	1	1	
IO	IO-D	3	66	19.59	2	1	2	1	0	1	1	1	
IO	IO-D	3	214	20.39	2	1	2	1	0	1	1	1	
IO	IO-D	3	34	20.77	2	1	2	2	0	1	1	1	
IO	IO-D	3	48	25.85	2	1	2	2	0	2	1	1	11
IO	IO-D	3	61	19.19	2	1	2	1	0	1	1	1	
IO	IO-D	3	76	86.06	2	1	2	1	0	2	1	1	
IO	IO-D	3	43	26.44	2	1	2	2	0	1	1	1	
IO	IO-D	4	120	24.38	2	1	1	1	6	2	2	1	

Note: See table 8.1 for the code description. Sampling Fraction is 100%. Variables: IG (Inside Glass), OG (Outside Glass), GCI (Glass Color Inside), GCO (Glass Color Outside), IS (Inside Surface), OS (Outside Surface), PC (Paste Color)

Appendix E.1 (Cont.): Data for recorded crucible fragments by excavation unit and level

Site	Unit	Level	Weight (g)	Thickness (mm)	Part of vessel	IG	OG	GCI	GCO	IS	OS	PC	<4cm (count)
IO	IO-D	4	69	25.63	2	1	1	1	2	1	2	1	
IO	IO-D	4	55	27.87	2	1	1	1	2	2	2	1	
IO	IO-D	4	34	14.85	2	1	2	1	0	2	1	1	
IO	IO-D	4	43	15.66	2	1	2	8	0	1	1	1	
IO	IO-D	4	41	18.73	2	1	2	1	0	2	2	1	
IO	IO-D	4	45	20	2	1	2	1	0	2	1	1	
IO	IO-D	4	41	20.53	2	1	2	1	0	2	1	1	
IO	IO-D	4	50	24.93	2	1	2	2	0	2	1	1	
IO	IO-D	4	45	20.89	2	2	1	0	2	1	2	1	
IO	IO-D	4	96	17.53	2	2	2	0	0	1	1	1	
IO	IO-D	4	26	20.36	2	2	2	0	0	1	1	1	22
IO	IO-D	4	38	23.34	2	2	2	0	0	2	2	1	
IO	IO-D	5	41	14.79	2	1	2	2	1	1	1	1	
IO	IO-D	5	39	14.85	2	1	2	1	0	2	2	1	
IO	IO-D	5	58	18.73	2	1	2	5	0	1	2	1	
IO	IO-D	5	51	20.15	2	1	2	1	0	1	1	1	
IO	IO-D	5	72	20.62	2	1	2	4	0	1	1	1	
IO	IO-D	5	44	21.11	2	1	2	1	0	1	1	1	
IO	IO-D	5	70	21.83	2	1	2	2	0	2	2	1	
IO	IO-D	5	70	24.05	2	1	2	1	0	1	1	1	
IO	IO-D	5	53	28.43	2	1	2	2	0	2	2	1	11
IO	IO-D	5	69	30.14	2	1	2	1	0	1	2	1	
IO	IO-D	5	80	30.53	2	1	2	1	0	1	2	1	
IO	IO-D	5	73	48.2	2	2	1	0	2	1	1	1	
IO	IO-D	5	91	17.85	2	2	2	0	0	1	1	1	
IO	IO-D	5	46	19.76	2	2	2	0	0	1	1	1	
IO	IO-D	5	42	22.01	2	2	2	0	0	1	2	1	
IO	IO-D	5	48	24.64	2	2	2	0	0	2	2	1	
IO	IO-D	5	66	30.64	2	1	2	1	0	1	2	1	
IO	IO-D	5	82	28.53	2	1	2	1	0	1	2	1	
IO	IO-D	5	53	40.84	2	2	2	0	0	2	1	1	
IO	IO-D	6	30	12.56	2	1	1	2	6	1	2	1	
IO	IO-D	6	33	15.82	2	1	1	1	2	2	1	1	
IO	IO-D	6	46	15.85	2	1	1	2	2	1	1	1	
IO	IO-D	6	25	18.99	2	1	1	1	2	1	1	1	
IO	IO-D	6	32	20.15	2	1	1	1	2	1	2	1	

Note: See table 8.1 for the code description. Sampling Fraction is 100%. Variables: IG (Inside Glass), OG (Outside Glass), GCI (Glass Color Inside), GCO (Glass Color Outside), IS (Inside Surface), OS (Outside Surface), PC (Paste Color)

Appendix E.1 (Cont.): Data for recorded crucible fragments by excavation unit and level

Site	Unit	Level	Weight (g)	Thickness (mm)	Part of vessel	IG	OG	GCI	GCO	IS	OS	PC	<4cm (count)
IO	IO-D	6	108	22.96	2	1	1	4	2	1	1	1	
IO	IO-D	6	44	24.76	2	1	1	2	2	1	1	1	
IO	IO-D	6	96	28.57	2	1	1	1	2	2	1	1	
IO	IO-D	6	39	30.05	2	1	1	1	1	1	2	1	
IO	IO-D	6	71	35.77	2	1	1	2	2	2	1	1	
IO	IO-D	6	41	36.3	2	1	1	2	6	2	2	1	
IO	IO-D	6	113	42.17	2	1	1	1	2	1	2	1	
IO	IO-D	6	37	17.7	2	1	2	1	0	2	1	1	
IO	IO-D	6	55	19.72	2	1	2	6	0	1	1	1	
IO	IO-D	6	41	19.75	2	1	2	1	0	1	1	1	
IO	IO-D	6	33	19.96	2	1	2	1	0	2	2	1	
IO	IO-D	6	77	20.22	2	1	2	9	0	1	1	1	
IO	IO-D	6	135	20.82	2	1	2	1	0	1	1	1	
IO	IO-D	6	34	20.98	2	1	2	1	0	2	1	1	
IO	IO-D	6	126	21.7	2	1	2	2	0	2	1	1	
IO	IO-D	6	39	23.04	2	1	2	1	0	2	1	1	
IO	IO-D	6	76	23.04	1	1	2	5	0	1	1	1	
IO	IO-D	6	206	23.76	2	1	2	2	0	1	2	1	
IO	IO-D	6	52	24.75	2	1	2	1	0	2	2	1	
IO	IO-D	6	23	24.83	2	1	2	2	0	1	2	1	
IO	IO-D	6	495	26.68	2	1	2	2	0	2	1	1	
IO	IO-D	6	37	28.53	2	1	2	4	0	1	1	1	
IO	IO-D	6	59	31.33	2	1	2	1	0	1	1	1	
IO	IO-D	6	66	32.07	2	1	2	2	0	1	1	1	
IO	IO-D	6	694	45.06	3	1	2	2	0	2	2	1	
IO	IO-D	6	43	20.55	2	2	1	0	2	1	1	1	
IO	IO-D	6	39	21.61	2	2	1	0	2	1	2	1	
IO	IO-D	6	141	22.04	1	2	1	0	1	1	1	1	
IO	IO-D	6	59	25.6	2	2	1	0	2	2	2	1	
IO	IO-D	6	95	32.39	3	2	1	0	6	1	2	1	
IO	IO-D	6	84	39.89	2	2	1	0	2	2	2	1	
IO	IO-D	6	40	20.75	2	1	2	1	0	1	1	1	
IO	IO-D	6	33	19.92	2	1	2	1	0	2	2	1	
IO	IO-D	6	392	42.93	3	2	1	0	2	2	1	1	
IO	IO-D	6	20	12.26	2	2	2	0	0	1	1	1	
IO	IO-D	6	45	15.25	2	2	2	0	0	1	2	1	

Note: See table 8.1 for the code description. Sampling Fraction is 100%. Variables: IG (Inside Glass), OG (Outside Glass), GCI (Glass Color Inside), GCO (Glass Color Outside), IS (Inside Surface), OS (Outside Surface), PC (Paste Color)

Appendix E.1 (Cont.): Data for recorded crucible fragments by excavation unit and level

Site	Unit	Level	Weight (g)	Thickness (mm)	Part of vessel	IG	OG	GCI	GCO	IS	OS	PC	<4cm (count)
IO	IO-D	6	26	18.71	2	2	2	0	0	1	1	1	
IO	IO-D	6	51	19.47	1	2	2	0	0	1	2	1	
IO	IO-D	6	53	21.89	2	2	2	0	0	1	1	1	
IO	IO-D	6	38	31.91	2	2	2		0	2	1	1	15
IO	IO-D	6	62	22.39	2	1	1	1	2	2	2	1	
IO	IO-D	6	31	22.73	1	1	1	2	2	2	1	1	
IO	IO-D	6	45	23.6	2	1	1	1	2	1	2	1	
IO	IO-D	6	80	24.13	2	1	1	1	6	1	2	1	
IO	IO-D	6	26	17.17	2	1	2	2	0	2	1	1	
IO	IO-D	6	63	18.94	2	1	2	1	0	1	1	1	
IO	IO-D	6	34	19.32	2	1	2	1	0	2	2	1	
IO	IO-D	6	35	19.9	2	1	2	2	0	2	2	1	
IO	IO-D	6	32	20	2	1	2	1	0	1	1	1	
IO	IO-D	6	40	23.69	2	1	2	5	0	2	2	1	
IO	IO-D	6	33	24.34	2	1	2	5	0	2	2	1	
IO	IO-D	6	29	24.93	2	1	2	5	0	2	1	1	
IO	IO-D	6	41	31.11	2	1	2	2	0	2	1	1	
IO	IO-D	6	48	36.87	2	1	2	2	0	2	2	1	
IO	IO-D	6	44	40.22	2	1	2	2	0	2	1	1	
IO	IO-D	6	118	22.94	2	2	1	0	2	2	2	1	
IO	IO-D	6	39	24.45	2	2	1	0	2	1	2	1	
IO	IO-D	6	53	23.33	2	2	2	0	0	1	2	1	
IO	IO-D	6	20	24.44	2	2	2	0	0	2	1	1	18
IO	IO-D	6	86	27.91	2	2	2	0	0	1	1	1	
IO	IO-D	6	154	32.74	2	2	2	0	0	2	2	1	
IO	IO-D	6	37	36.28	2	2	2	0	0	2	2	1	
IO	IO-D	6	105	26.29	2	1	1	4	2	1	2	1	
IO	IO-D	6	26	20.66	2	1	2	1	0	1	2	1	3
IO	IO-D	6	53	26.29	2	1	2	1	0	1	1	1	
IO	IO-D	7	24	13.28	1	1	1	4	4	1	1	1	
IO	IO-D	7	44	17.61	1	1	1	2	9	1	2	1	
IO	IO-D	7	166	22.05	2	1	1	2	2	1	1	1	
IO	IO-D	7	43	23.69	2	1	1	1	2	2	1	1	
IO	IO-D	7	39	23.8	2	1	1	1	2	2	1	1	
IO	IO-D	7	26	31.4	2	1	1	2	9	2	2	1	
IO	IO-D	7	436	51.55	3	1	1	2	6	2	2	1	
IO	IO-D	7	40	18.52	2	1	2	1	0	1	1	1	

Note: See table 8.1 for the code description. Sampling Fraction is 100%. Variables: IG (Inside Glass), OG (Outside Glass), GCI (Glass Color Inside), GCO (Glass Color Outside), IS (Inside Surface), OS (Outside Surface), PC (Paste Color)

Appendix E.1 (Cont.): Data for recorded crucible fragments by excavation unit and level

Site	Unit	Level	Weight (g)	Thickness (mm)	Part of vessel	IG	OG	GCI	GCO	IS	OS	PC	<4cm (count)
IO	IO-D	7	65	23.88	2	1	2	1	0	2	1	1	
IO	IO-D	7	56	26.64	2	1	2	1	0	2	2	1	
IO	IO-D	7	53	21.5	2	2	1	0	2	1	2	1	
IO	IO-D	7	21	19.96	2	2	2	0	0	2	1	1	9
IO	IO-D	7	404	38.1	2	2	2	0	0	1	2	1	
IO	IO-D	7	35	19.66	1	1	1	1	2	2	1	1	
IO	IO-D	7	274	21.27	2	1	1	1	2	2	2	1	
IO	IO-D	7	195	23.8	1	1	1	1	2	1	2	1	
IO	IO-D	7	303	41.3	2	1	1	2	6	2	1	1	
IO	IO-D	7	44	18.35	2	1	2	2	0	1	1	1	
IO	IO-D	7	47	18.44	2	1	2	2	0	2	2	1	
IO	IO-D	7	69	27.12	2	1	2	2	0	2	2	1	
IO	IO-D	7	79	28.4	2	1	2	2	0	2	2	1	
IO	IO-D	7	45	21.87	2	2	1	2	6	1	1	1	
IO	IO-D	7	38	20.53	2	2	2	0	0	1	1	1	16
IO	IO-E	1	56	16.87	2	1	1	2	2	1	1	1	
IO	IO-E	1	35	20.36	2	1	1	1	6	2	2	1	
IO	IO-E	1	43	17.08	2	1	2	0	0	1	2	1	
IO	IO-E	1	37	17.49	2	1	2	2	0	1	2	1	
IO	IO-E	1	37	14.83	2	2	2	4	9	1	1	1	3
IO	IO-E	2	31	18.56	1	1	1	1	1	1	2	1	
IO	IO-E	2	247	21.37	2	1	1	2	2	2	1	1	
IO	IO-E	2	27	14.94	2	1	2	2	0	1	1	1	21
IO	IO-E	2	68	19.17	1	1	2	2	0	1	1	1	
IO	IO-E	2	58	22.7	2	1	2	5	0	1	1	1	
IO	IO-E	2	50	24.78	2	1	2	1	0	1	1	1	
IO	IO-E	2	94	25.27	2	1	2	2	0	2	1	1	

Note: See table 8.1 for the code description. Sampling Fraction is 100%. Variables: IG (Inside Glass), OG (Outside Glass), GCI (Glass Color Inside), GCO (Glass Color Outside), IS (Inside Surface), OS (Outside Surface), PC (Paste Color)

Appendix E.1 (Cont.): Data for recorded crucible fragments by excavation unit and level

Site	Unit	Level	Weight (g)	Thickness (mm)	Part of vessel	IG	OG	GCI	GCO	IS	OS	PC	<4cm (count)
IO	IO-E	2	68	25.69	2	1	2	2	0	2	2	1	
IO	IO-E	2	87	33.01	2	1	2	2	0	2	2	1	
IO	IO-E	2	43	20.7	2	2	2	0	0	1	2	1	
IO	IO-E	3	28	35.8	2	1	1	2	2	1	2	1	
IO	IO-E	3	169	56.91	2	1	1	1	1	1	1	1	
IO	IO-E	3	43	16.81	2	1	2	2	0	1	1	1	
IO	IO-E	3	35	31.01	2	1	2	4	0	1	1	1	
IO	IO-E	3	105	44.5	2	1	2	2	0	2	1	1	
IO	IO-E	3	34	22.07	2	2	2	0	0	1	2	1	9
OO	OO-A	1	45	19.59	2	1	2	1	0	1	1	1	
OO	OO-A	7	28	16.23	2	1	2	1	0	1	1	1	3

Note: See table 8.1 for the code description. Sampling Fraction is 100%. Variables: IG (Inside Glass), OG (Outside Glass), GCI (Glass Color Inside), GCO (Glass Color Outside), IS (Inside Surface), OS (Outside Surface), PC (Paste Color)

Appendix E.2: crucible fragments from Igbo-Olokun excavations showing different interior glass color

Appendix E. 3: Data for recorded ceramic cylinder by excavation unit and level

UNIT	LEVEL	Weight	Diameter/ Thickness	End Form	Surface Condition	Degree of Fire	Paste Color	Core	Texture
IO-A	1	7	19.72	2	1	0	1	2	Medium paste
IO-A	1	5	17.15	2	2	1	1	2	Fine Paste
IO-A	1	8	16.7	2	2	2	1	2	Coarse Paste
IO-A	1	7	15.63	2	2	1	1	2	Coarse Paste
IO-A	1	5	15.38	3	2	2	1	2	Coarse paste
IO-A	3	16	22.69	2	2	1	2	1	Coarse Paste
IO-A	3	9	22.31	2	2	1	2	1	Fine Paste
IO-A	3	12	17.8	2	2	2	2	1	Coarse Paste
IO-A	3	8	15.24	2	1	0	2	1	Coarse Paste
IO-A	3	9	15.97	2	2	2	2	1	Coarse Paste
IO-A	3	9	13.45	3	2	1	2	1	Medium paste
IO-A	3	7	15.77	2	2	1	2	1	Medium paste
IO-A	3	5	15.71	2	2	1	2	1	Coarse Paste
IO-A	3	5	17.6	2	2	1	2	1	Medium paste
IO-A	3	4	13.93	1	1	0	1	1	Medium paste
IO-A	3	5	15.28	2	1	0	1	2	Coarse Paste
IO-A	3	4	13.65	2	1	0	1	2	Medium paste
IO-A	3	4	15.5	2	1	0	1	2	Fine Paste
IO-A	3	2	15.64	2	2	2	2	1	Medium paste
IO-A	4	15	18.48	2	2	1	2	1	Coarse Paste
IO-A	4	24	24.22	2	1	0	2	1	Fine Paste
IO-B	1	17	19.17	2	1	0	2	1	Medium paste
IO-B	2	4	15.46	3	2	1	1	1	Coarse Paste
IO-B	2	18	20.55	2	2	1	1	2	Medium paste
IO-B	2	12	19.56	2	1	0	1	2	Medium paste
IO-B	4	36	26.22	2	2	1	2	1	Medium paste
IO-B	4	27	23.33	2	2	1	2	1	Medium paste
IO-B	4	14	17.96	2	1	0	2	1	Coarse Paste
I0-B	4	27	27.17	2	2	2	2	1	Coarse Paste
IO-B	4	26	22.31	2	2	1	2	1	Fine Paste
IO-B	4	19	23.31	1	1	0	2	1	Medium paste
IO-B	4	11	13.62	3	2	2	2	1	Coarse Paste
IO-B	4	30	17.11	2	2	1	2	1	Medium paste
IO-B	4	13	17.03	2	2	2	2	1	Fine Paste
IO-B	4	19	20.81	1	2	2	2	1	Medium paste

Appendix E. 3 (Cont.): Data for recorded ceramic cylinder by excavation unit and level

UNIT	LEVEL	Weight	Diameter/ Thickness	End Form	Surface Condition	Degree of Fire	Paste Color	Core	Texture
IO-B	4	10	19.29	2	1	0	2	1	Medium paste
IO-B	4	12	16.71	2	2	1	2	1	Fine Paste
IO-B	4	12	19.07	2	1	0	2	1	Coarse Paste
IO-B	4	16	18.18	2	1	0	2	1	Medium paste
IO-B	4	12	18.02	1	1	0	2	1	Coarse Paste
IO-B	4	13	18.51	1	2	0	2	1	Coarse Paste
IO-B	4	10	19.65	2	1	1	2	1	Medium paste
IO-B	4	8	26.53	2	2	0	2	1	Coarse Paste
IO-B	4	10	15.75	2	1	1	2	1	Medium paste
IO-B	4	9	16.3	2	2	0	2	1	Medium paste
IO-B	4	8	17.11	2	2	1	1	2	Fine Paste
IO-B	4	7	15.63	2	1	0	2	1	Fine Paste
IO-B	4	8	16.76	2	2	1	2	1	Fine Paste
IO-B	4	9	7.01	2	1	0	2	1	Coarse Paste
IO-B	4	6	18.8	1	2	1	2	1	Fine Paste
IO-B	4	5	15.9	1	1	0	2	1	Coarse Paste
IO-B	4	4	13.71	2	1	0	0	2	Medium paste
IO-B	4	7	17.5	2	2	1	2	1	Fine Paste
IO-B	4	5	20.01	2	1	0	2	1	Coarse Paste
IO-B	4	7	18.97	1	1	1	1	2	Fine Paste
IO-B	4	3	12.79	1	1	0	1	2	Coarse Paste
IO-B	4	3	13.49	3	2	1	1	2	Coarse Paste
IO-B	4	3	17.65	2	2	1	2	1	Medium paste
IO-B	5	17	19.9	2	2	1	1	2	Fine Paste
IO-B	5	17	15.07	2	1	0	2	1	Medium paste
IO-B	5	10	16.47	2	1	0	2	1	Fine Paste
IO-B	5	6	17.12	2	1	0	2	1	Medium paste
IO-B	5	9	17.14	2	1	0	2	1	Coarse Paste
IO-B	5	15	21.01	2	1	0	2	1	Medium paste
IO-B	5	18	23.67	2	2	1	2	1	Coarse Paste
IO-B	5	14	19.6	2	2	1	2	1	Coarse Paste
IO-B	5	8	19.24	2	2	1	2	1	Medium paste
IO-B	5	10	18.04	2	2	1	2	1	Fine Paste
IO-B	5	6	16.35	3	2	2	2	1	Fine Paste
IO-B	5	7	18.04	2	2	1	1	1	Fine Paste
IO-B	5	4	21.13	3	2	2	2	1	Coarse Paste

Appendix E. 3 (Cont.): Data for recorded ceramic cylinder by excavation unit and level

UNIT	LEVEL	Weight	Diameter/ Thickness	End Form	Surface Condition	Degree of Fire	Paste Color	Core	Texture
IO-B	6	20	22.8	3	2	1	2	1	Coarse Paste
IO-B	6	13	15.53	1	2	1	2	1	Medium paste
IO-B	6	10	14.72	1	2	2	2	1	Fine Paste
IO-B	6	10	15.84	2	1	0	2	1	Medium paste
IO-B	6	6	22.49	2	1	0	2	1	Coarse Paste
IO-B	6	5	17.81	2	2	2	2	1	Coarse Paste
IO-B	6	6	17.44	2	1	0	2	1	Medium paste
IO-B	6	3	12.26	2	1	0	2	1	Coarse Paste
IO-B	7	29	28.7	2	2	1	2	1	Fine Paste
IO-B	7	21	26.19	2	2	1	2	1	Fine Paste
IO-B	7	16	16.65	2	2	1	2	1	Coarse Paste
IO-B	7	12	16.28	2	2	1	2	1	Medium paste
IO-B	7	7	16.21	2	2	1	2	1	Medium paste
IO-B	7	12	19.37	2	2	1	2	1	Medium paste
IO-B	7	7	15.22	2	2	1	2	1	Fine Paste
IO-B	7	9	18.45	2	2	1	2	1	Fine Paste
IO-B	7	8	16.07	2	2	0	2	1	Fine Paste
IO-B	7	5	16.82	2	2	1	2	1	Coarse Paste
IO-B	7	5	14.01	1	1	0	2	1	Coarse Paste
IO-B	8	31	25.89	2	2	1		1	Medium paste
IO-B	8	24	23.87	2	2	1	2	1	Fine Paste
IO-B	8	9	20.83	2	1	0	2	1	Fine Paste
IO-B	8	18	23.58	1	2	1	2	1	Medium paste
IO-B	8	14	18.49	2	2	1	2	1	Medium paste
IO-B	8	9	22.12	1	1	0	2	1	Fine Paste
IO-B	8	9	15.61	2	1	0	2	1	Medium paste
IO-B	8	7	17.24	1	2	1	2	1	Fine Paste
IO-B	8	7	17.43	2	1	0	2	1	Coarse Paste
IO-B	8	7	16.84	2	1	0	2	1	Coarse Paste
IO-B	8	2	16.33	2	1	0	2	1	Fine Paste
IO-C	1	7	20.48	2	2	1	2	1	Coarse Paste
IO-C	1	6	15.7	2	1	0	2	1	Medium paste
IO-C	1	4	18.04	2	2	1	2	1	Coarse Paste
IO-C	2	15	21.1	2	2	1	2	1	Fine Paste
IO-C	2	17	17.26	2	1	0	2	1	Fine Paste
IO-C	2	15	17.96	2	1	0	2	1	Medium paste

Appendix E. 3 (Cont.): Data for recorded ceramic cylinder by excavation unit and level

UNIT	LEVEL	Weight	Diameter/ Thickness	End Form	Surface Condition	Degree of Fire	Paste Color	Core	Texture
IO-C	2	8	16.64	2	1	0	2	1	Medium paste
IO-C	2	9	15.67	2	2	2	2	1	Coarse Paste
IO-C	2	5	17.33	2	1	0	2	1	Medium paste
IO-C	2	5	17.68	3	1	0	2	1	Medium paste
IO-C	2	2	12.86	3	1	0	2	1	Fine Paste
IO-C	3	7	16.19	2	2	2	2	1	Coarse Paste
IO-C	3	6	15.4	2	1	0	2	1	Coarse Paste
IO-C	3	6	14.86	2	1	0	1	2	Fine Paste
IO-C	3	5	15.64	2	1	0	2	1	Medium paste
IO-C	3	5	16.87	2	2	1	1	2	Coarse Paste
IO-C	3	3	13.63	2	2	1	2	1	Fine Paste
IO-C	4	44	25.35	2	2	2	2	1	Coarse Paste
IO-C	4	16	18.7	2	1	0	2	1	Coarse Paste
IO-C	4	16	20.17	2	2	0	2	1	Medium paste
IO-C	4	16	18.11	2	2	1	2	1	Coarse Paste
IO-C	4	17	24.89	1	2	1	2	1	Medium paste
IO-C	4	8	16.21	1	2	1	2	1	Coarse Paste
IO-C	4	7	16.1	1	2	1	2	1	Medium paste
IO-C	4	7	17.86	2	1	0	2	1	Coarse Paste
IO-C	4	5	19.66	2	1	0	2	1	Medium paste
IO-C	4	4	13.22	3	2	2	2	1	Medium paste
IO-C	4	4	15.87	2	1	0	2	1	Coarse Paste
IO-C	5	17	19.73	1	2	1	2	1	Medium paste
IO-C	5	19	22.38	1	2	1	2	1	Medium paste
IO-C	5	12	23.96	2	2	1	2	1	Coarse Paste
IO-C	5	8	15.84	2	1	0	2	1	Coarse Paste
IO-C	5	9	19.58	2	2	1	2	1	Coarse Paste
IO-C	5	6	19.5	2	1	0	2	1	Coarse Paste
IO-C	5	3	9	1	2	1	2	1	Coarse Paste
IO-C	5	3	14.68	2	1	0	2	1	Medium paste
IO-C	6	12	15.84	2	2	1	2	1	Fine Paste
IO-C	6	8	15.32	2	2	1	2	1	Medium paste
IO-C	6	10	17.45	2	1	0	2	1	Medium paste
IO-C	6	6	15.26	1	1	0	2	1	Coarse Paste
IO-C	6	9	18.43	2	1	0	2	1	Fine Paste
IO-C	6	9	16.91	1	2	1	2	1	Coarse Paste

Appendix E. 3 (Cont.): Data for recorded ceramic cylinder by excavation unit and level

UNIT	LEVEL	Weight	Diameter/ Thickness	End Form	Surface Condition	Degree of Fire	Paste Color	Core	Texture
IO-C	6	9	18.83	2	1	2	2	1	Medium paste
IO-C	6	7	18.26	2	1	0	2	1	Medium paste
IO-C	6	7	14.67	2	2	1	2	1	Medium paste
IO-C	6	4	16	3	2	1	2	1	Coarse Paste
IO-C	6	3	19.38	2	1	2	1	2	Coarse Paste
IO-C	6	4	15.51	2	1	0	2	2	Fine Paste
IO-C	6	2	15.93	2	1	0	2	1	Medium paste
IO-C	7	11	21.1	2	2	2	2	1	Medium paste
IO-C	7	13	22.24	2	2	2	2	1	Coarse Paste
IO-C	7	6	16.19	1	1	0	2	1	Medium paste
IO-C	7	8	19.19	2	2	1	2	1	Coarse Paste
IO-C	7	3	17.22	2	1	0	2	1	Medium paste
IO-D	1	11	18.53	2	2	1	2	1	Coarse Paste
IO-D	1	15	19.44	2	1	0	2	1	Coarse Paste
IO-D	1	11	16.64	2	1	0	2	1	Coarse Paste
IO-D	1	7	16.08	2	1	0	2	1	Medium paste
IO-D	1	14	23.34	1	1	0	2	1	Fine Paste
IO-D	2	45	28.23	2	2	1	2	1	Medium paste
IO-D	2	34	23.87	2	2	1	2	1	Medium paste
IO-D	2	10	17.22	2	1	0	2	1	Coarse Paste
IO-D	2	14	22.35	1	1	0	2	1	Coarse Paste
IO-D	2	7	16.82	1	1	0	2	1	Coarse Paste
IO-D	2	7	16.59	1	2	2	2	1	Coarse Paste
IO-D	2	7	17.84	2	2	1	2	1	Medium paste
IO-D	3	17	26.53	2	2	1	2	1	Medium paste
IO-D	3	12	17.02	2	1	0	2	1	Coarse Paste
IO-D	3	6	15.11	3	1	0	2	1	Medium paste
IO-D	3	7	17.19	2	2	1	2	1	Medium paste
IO-D	3	7	13.74	2	1	0	2	1	Medium paste
IO-D	3	6	16.78	2	1	0	2	1	Coarse Paste
IO-D	3	3	13.44	3	2	2	2	1	Medium paste
IO-D	3	22	25.04	2	2	1	2	1	Medium paste
IO-D	3	14	16.11	1	2	1	2	1	Medium paste
IO-D	4	28	25.28	1	2	1	2	1	Coarse Paste
IO-D	4	12	16.29	2	2	1	2	1	Medium paste
IO-D	4	13	1.12	2	1	0	2	1	Medium paste

Appendix E. 3 (Cont.): Data for recorded ceramic cylinder by excavation unit and level

UNIT	LEVEL	Weight	Diameter/ Thickness	End Form	Surface Condition	Degree of Fire	Paste Color	Core	Texture
IO-D	4	8	15.68	2	2	1	2	1	Coarse Paste
IO-D	4	12	18.64	2	2	2	2	1	Fine Paste
IO-D	4	8	15.16	2	2	1	2	1	Medium paste
IO-D	4	8	18.34	2	1	0	2	1	Fine Paste
IO-D	4	3	10.07	2	2	1	1	2	Fine Paste
IO-D	6	12	16.77	2	2	1	2	1	Fine Paste
IO-D	6	10	12.13	2	1	0	2	1	Medium paste
IO-D	6	10	15.47	1	1	0	2	1	Medium paste
IO-D	6	9	18.49	2	2	1	2	1	Fine Paste
IO-D	6	8	16.41	2	1	0	2	1	Medium paste
IO-D	6	7	15.86	2	1	0	2	1	Fine Paste
IO-D	6	4	14.33	1	2	1	2	1	Medium paste
IO-D	6	9	17.34	2	1	0	2	1	Medium paste
IO-D	6	6	19.53	3	2	1	2	1	Fine Paste
IO-D	6	3	17.08	2	1	0	2	1	Fine Paste
IO-D	6	12	16.58	1	1	0	2	1	Medium paste
IO-D	7 Pit 1	27	19.1	2	1	0	2	1	Medium paste
IO-D	7 Pit 1	10	20.15	1	1	0	2	1	Medium paste
IO-D	7 Pit 2	9	17.13	2	2	2	2	1	Fine Paste
IO-D	7 Pit 2	11	17.26	1	2	1	2	1	Coarse Paste
IO-D	7 pit 2	23	20.39	2	2	1	2	1	Medium paste
IO-D	7 pit 2	16	16.71	2	2	1	2	1	Medium paste
IO-D	7 pit 2	13	16.93	2	1	0	2	1	Coarse Paste
IO-D	7 pit 2	9	16.76	2	1	0	2	1	Coarse Paste
IO-D	7 pit 2	8	18.26	2	2	1	2	1	Medium paste
IO-D	7 pit2	15	17.05	2	1	0	2	1	Medium paste

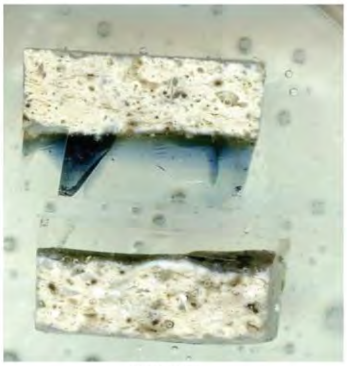
Appendix E.4: Grouping of production debris into different stages in bead production

Unit	Level	Glass Debris	Tube Drawing Waste	Beadmaking Waste	Count	Weight (gr)	Comments
IO-C	5	FK			133	8.6	
IO-C	5	CK			127	38.1	
IO-C	5	GD			15	1.7	
IO-C	5	PD			14	2.7	
IO-C	5	FC			21	3.4	
IO-C	5	GGF			134	4.2	
IO-C	5		TT		1	0.2	
IO-C	5		UC		9	0.3	
IO-C	5		AS		6	1.2	
IO-C	5		FT		66	5.2	
IO-C	5		CT		45	4.9	
IO-C	5		FDT		1	0.2	
IO-C	5		BTF		195	14.1	
IO-C	5		HM		16	1.3	
IO-C	5			MB	28	1	
IO-C	5			CP	1	0.2	
IO-C	5			MF	64	4.6	1 is white or heavily patinated
IO-D	6	FK			217	16.1	
IO-D	6	CK			248	67.7	
IO-D	6	GD			27	4.8	
IO-D	6	PD			13	0.7	
IO-D	6	FC			27	4.7	
IO-D	6	GGF			260	11.5	
IO-D	6		TT		1	0.2	
IO-D	6		UC		12	1	
IO-D	6		AS		12	2.4	
IO-D	6		FT		294	23.3	
IO-D	6		CT		124	12.7	
IO-D	6		FDT		9	0.5	
IO-D	6		BTF		487	38.5	9 are white or heavily patinated
IO-D	6		HM		34	3.8	
IO-D	6			MB	79	2.1	
IO-D	6			CP	0	0	

Appendix E.4 (Cont.): Grouping of production debris into different stages in bead production

Unit	Level	Glass Debris	Tube Drawing Waste	Beadmaking Waste	Count	Weight (gr)	Comments
IO-D	6			MF	48	2.7	
IO-B	4	FK			98	5.3	
IO-B	4	CK			74	33	
IO-B	4	GD			10	1.3	
IO-B	4	PD			0	0	
IO-B	4	FC			33	4	
IO-B	4	GGF			46	2.3	
IO-B	4		TT		0	0	
IO-B	4		UC		0	0	
IO-B	4		AS		2	1.6	
IO-B	4		FT		43	3.7	
IO-B	4		CT		34	3.2	
IO-B	4		FDT		2	0.2	
IO-B	4		BTF		164	14.2	
IO-B	4		HM		4	0.2	
IO-B	4			MB	41	1.2	
IO-B	4			CP	0	0	
IO-B	4			MF	77	4.1	
Total					3396		

Appendix E.5: Prepared samples for SEM/EDS analysis (provenience is described in appendix E.6)



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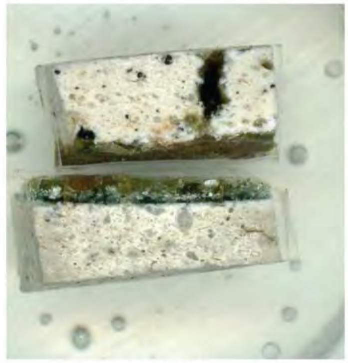
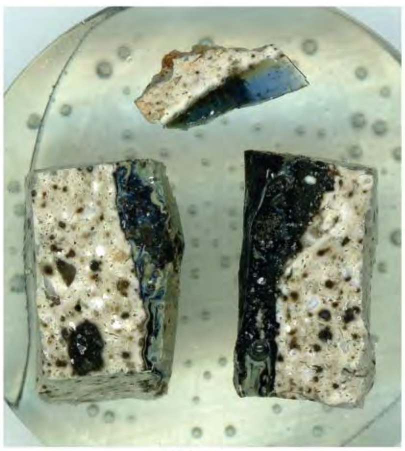


IFCC4

IF0072



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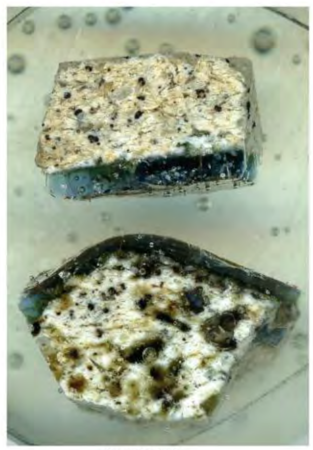


IF0075

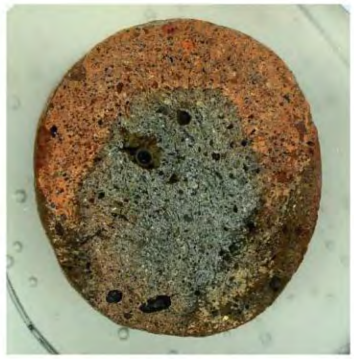
IF0076

IF0077

IF0078

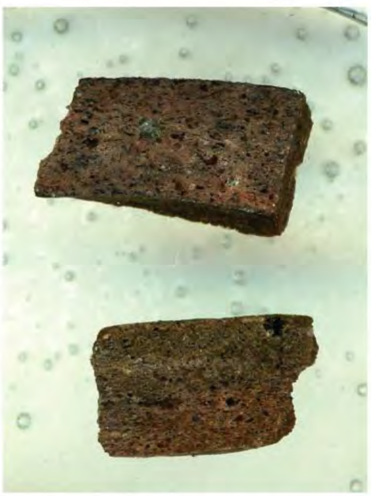
Appendix E. 5 (Cont.): Prepared samples for SEM/EDS analysis (provenience is described in appendix E.6).

IF0080



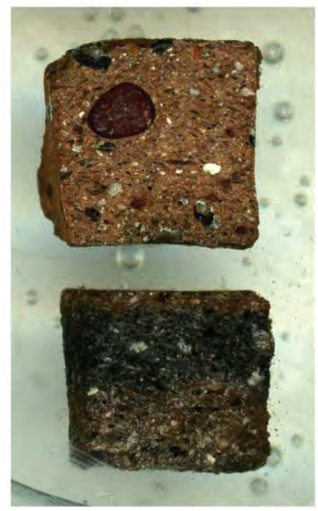
IF0081

IF0082



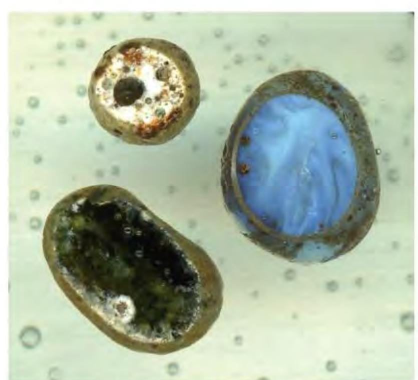
IF0087 (top); IF0088 (bottom)

IF0089 (top); IF0090 (bottom)



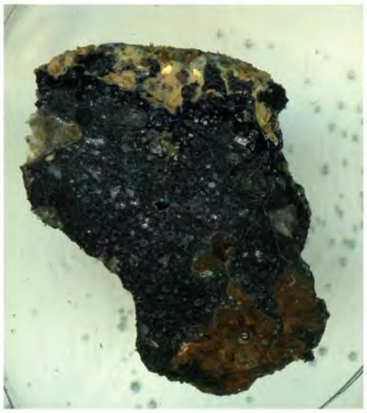
IF0091 (top); IF0092 (bottom)

IF0083 (right two); IF0084 (left one)



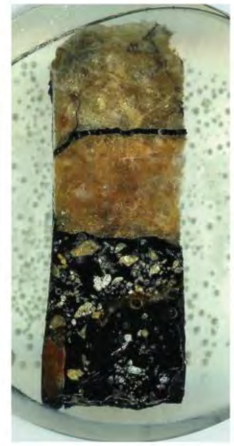
IF0085 (all three)

Appendix E.5 (Cont.): Prepared samples for SEM/EDS analysis (provenience is described in appendix E.6).



IF0093

IF0094



IF0095

IF0096

IF0097

Appendix E.6: Provenience and description of the Crucible Samples Analyzed by SEM-EDS

Unit	Level	Sample #	Thickness	Vessel Part	Int. Glass Color	Ext. Glaze	Fabric Color	Comments
Surface		IFE CC 1	2.4	Body	Blue	Yes	White	Interior glass very dark blue to the point of mistaking for black. Smooth glass interior. The exterior glaze is tin
Surface		IFE CC4	1.9	Body	Light Green	Yes	White	Interior glass is smooth and not ridges are noticed. There is blue tint in the background of interior glass color. The exterior glaze is tin.
IO-B/D	7	IF0072	1.2	Body	Red	Yes	White	The exterior glaze is very tin to the point of almost not visible visually. There is black glass mixture with the red glass on the interior.
IO-A	4	IF0073	3.7	Body	Blue	Yes	Dark gray	Thick exterior glaze. Cross section shows shades of blue in the exterior glaze, from pale blue to dark blue
IO-C	7	IF0074	1.9	Body	Blue	Yes	White	The exterior glaze is tin
IO-B/D	7	IF0075	2.2	Rim	Blue	Yes	White	The exterior glaze appears to be blue glass that has been contaminated with fuel ash or smoke, which changed the color from blue, as in the case on the interior, to greenish. The exterior glaze/glass is restricted to the upper part of the rim fragment
IO-D	2	IF0076	1.8	Body	Light Green	Yes	Light gray	The exterior glaze is tin. The surface of the interior glass appears off-white but turns light green in the cross section. The surface discoloration may indicate initial stage of corrosion
OO-A	2	IF0077	2.1	Body	Red	Yes	off-white	There is blue mix in the interior glass.
IO-B/D	7	IF0078	3.8	Body	White	Yes	off-white	the interior glass is chalky and non-glass, which suggest that the glass is badly corroded
IO-C	7	IF0079	1.9	Body	Black/dark gray	Yes	off-white	Both the interior glass and exterior glaze are thin

Appendix E. 7: Chemical composition of all the areas and spots analyzed in the crucible by SEM-EDS

Material	**Sample #**	**Area analyzed**	**Na_2O**	**MgO**	**Al_2O_3**	**SiO_2**	**P_2O_5**	**Cl**	**K_2O**	**CaO**	**TiO_2**	**MnO**	**FeO**	**CuO**	**Total**
Crucible	IFCC 1	Out glaze 1	0.2	3.8	17.5	45.3	0.6	0.0	9.6	20.0	0.7	0.3	2.0	0.0	100.0
Crucible	IF CC4	Out glaze	1.0	2.3	15.4	50.5	1.3	0.0	5.0	20.3	0.8	0.2	3.1	0.0	100.0
Crucible	IF0072	Out glaze 1	0.7	3.6	13.1	44.4	1.5	0.0	8.5	25.9	0.5	0.1	1.7	0.0	100.0
Crucible		Out glaze 2	0.6	3.8	13.3	42.9	1.6	0.0	7.3	28.0	0.5	0.1	2.0	0.0	100.0
Crucible		Out glaze 3	0.3	0.3	27.5	60.6	0.1	0.0	9.0	0.6	0.2	0.0	1.5	0.0	100.0
Crucible	IF0073	Out glaze 1	0.2	4.2	13.0	51.5	1.4	0.0	6.6	16.1	1.6	0.4	4.9	0.0	100.0
Crucible		Out glaze 2	0.3	3.9	15.5	48.3	1.2	0.0	6.2	15.1	1.4	0.3	7.9	0.0	100.0
Crucible		Out glaze 3	0.2	1.6	13.8	64.5	0.5	0.0	5.7	5.1	2.2	0.2	6.3	0.0	100.0
Crucible	IF0074	Out glaze 1	2.0	1.3	15.0	61.5	1.7	0.0	9.2	5.2	1.6	0.2	2.4	0.0	100.0
Crucible		Out glaze 2	2.1	0.7	15.4	60.9	4.0	0.0	8.6	3.8	1.2	0.2	3.0	0.0	100.0
Crucible	IF0075	Out glaze	3.9	0.2	11.9	64.9	0.2	0.0	3.2	14.2	0.2	0.9	0.5	0.0	100.0
Crucible	IF0076	Out glaze 1	0.0	0.2	22.3	52.4	2.2	0.1	19.6	1.2	0.6	0.3	1.3	0.0	100.0
Crucible		Out glaze 2	0.4	0.2	38.0	51.2	0.1	0.0	8.6	0.2	0.2	0.0	1.2	0.0	100.0
Crucible		Out glaze 3	0.3	0.3	17.9	62.2	0.1	0.0	17.9	0.7	0.0	0.0	0.8	0.0	100.0
Crucible	IF0077	Out glaze 1	0.5	0.5	16.4	63.1	0.8	0.0	3.9	3.3	3.7	0.2	7.6	0.0	100.0
Crucible		Out glaze 2	0.5	0.6	19.6	59.2	0.6	0.1	3.8	5.2	2.9	0.1	7.4	0.0	100.0
Crucible	IF0078	Out glaze 1	1.0	5.4	12.6	50.6	2.6	0.0	5.3	15.1	2.0	1.0	4.6	0.0	100.0
Crucible		Out glaze 2	0.1	0.0	23.7	53.8	0.3	0.1	21.3	0.2	0.2	0.0	0.2	0.0	100.0
Crucible	IF0079	Out glaze 1	1.4	2.9	11.2	55.3	1.4	0.0	9.8	10.8	2.0	0.4	4.9	0.0	100.0
Crucible		Out glaze 2	1.1	3.3	10.8	54.0	1.7	0.0	8.3	13.5	1.9	0.6	4.9	0.0	100.0
Crucible	IFCC 1	Out body 1	0.1	0.1	34.5	55.8	0.2	0.0	7.1	0.1	0.3	0.1	1.9	0.0	100.0
Crucible		Out body 2	0.1	0.1	27.4	65.6	0.0	0.0	4.9	0.1	0.2	0.1	1.5	0.0	100.0
Crucible	IF CC4	Out body 1	0.2	0.2	28.0	65.8	0.0	0.2	3.1	0.1	0.5	0.0	1.9	0.0	100.0
Crucible		Out body 2	0.3	0.2	30.9	62.3	0.1	0.2	3.6	0.2	0.4	0.0	2.0	0.0	100.1

Appendix E. 7 (Cont.): Chemical composition of all the areas and spots analyzed in the crucible by SEM-EDS

Material	**Sample #**	**Area analyzed**	**Na2O**	**MgO**	**Al2O3**	**SiO2**	**P2O5**	**Cl**	**K2O**	**CaO**	**TiO2**	**MnO**	**FeO**	**CuO**	**Total**
Crucible	IF0072	Out body	0.3	0.7	34.2	53.0	0.1	0.0	8.7	1.4	0.2	0.1	1.4	0.0	100.0
Crucible	IF0073	Out body 1	0.1	0.0	33.0	58.2	0.0	0.0	4.9	0.1	0.7	0.0	2.9	0.0	100.0
Crucible		Out body 2	0.2	0.1	29.0	62.0	0.1	0.0	5.1	0.3	0.7	0.1	2.6	0.0	100.0
Crucible	IF0074	Out body 1	0.3	0.1	34.1	59.8	0.0	0.2	3.3	0.1	0.3	0.0	1.8	0.0	100.0
Crucible		Out body 2	0.2	0.1	35.7	59.3	0.0	0.1	2.6	0.1	0.1	0.0	1.7	0.0	100.0
Crucible		Out body vit area 1	2.1	0.8	30.1	53.4	0.8	0.0	8.2	2.1	0.5	0.0	2.1	0.0	100.0
Crucible		Out body vit area 2	1.4	0.7	23.4	54.5	0.9	0.1	13.1	4.1	0.5	0.0	1.3	0.0	100.0
Crucible		Out body vit area 3	0.4	0.2	36.3	57.7	0.1	0.1	3.0	0.2	0.2	0.0	2.0	0.0	100.0
Crucible	IF0075	Out body 1	0.2	0.2	28.4	62.0	0.0	0.2	3.3	0.4	1.4	0.1	3.8	0.0	100.0
Crucible		Out body 2	0.3	1.3	22.9	62.6	0.5	0.0	4.4	4.2	0.7	0.2	3.2	0.0	100.0
Crucible		Out body 3	0.8	0.3	26.3	60.9	0.3	0.0	7.7	0.5	1.1	0.1	2.0	0.0	100.0
Crucible	IF0076	Out body 1	0.3	0.3	24.2	67.1	0.1	0.0	6.6	0.3	0.2	0.0	1.0	0.0	100.0
Crucible		Out body 2	0.2	0.2	31.4	62.0	0.0	0.1	4.0	0.1	0.2	0.0	1.8	0.0	100.0
Crucible	IF0077	Out body 1	0.3	0.2	35.6	56.2	0.2	0.2	3.8	0.0	0.2	0.0	3.3	0.0	100.0
Crucible		Out body 2	0.2	0.2	37.4	54.0	0.2	0.3	3.7	0.1	0.2	0.1	3.8	0.0	100.0
Crucible		Out body 3	0.4	0.1	33.9	56.2	0.1	0.0	4.8	1.2	0.5	0.0	3.0	0.0	100.0
Crucible	IF0078	Out body 1	0.1	0.1	35.8	57.1	0.0	0.2	4.1	0.1	1.0	0.0	1.6	0.0	100.0
Crucible		Out body 2	0.1	0.1	36.2	57.3	0.0	0.3	3.8	0.1	0.3	0.1	1.7	0.0	100.0
Crucible	IF0079	Out body 1	0.3	0.1	35.0	56.2	0.1	0.2	6.3	0.2	0.2	0.1	1.4	0.0	100.0
Crucible		Out body 2	0.3	0.2	35.7	55.6	0.1	0.1	5.7	0.1	0.2	0.0	2.0	0.0	100.0
Crucible		Out body vit area	0.5	0.9	32.1	55.0	0.3	0.0	7.6	1.3	0.5	0.1	1.8	0.0	100.0

Appendix E. 7 (Cont.): Chemical composition of all the areas and spots analyzed in the crucible by SEM-EDS

Material	Sample #	Area analyzed	Na2O	MgO	Al2O3	SiO2	P2O5	Cl	K2O	CaO	TiO2	MnO	FeO	CuO	Total
Crucible	IFCC 1	In body	0.8	0.1	32.5	59.9	0.0	0.1	4.7	0.1	0.1	0.0	1.8	0.0	100.0
Crucible	IF CC4	In Body 1	0.5	0.2	29.0	64.6	0.0	0.2	2.3	0.1	0.6	0.0	2.4	0.0	100.0
Crucible		In Body 2	0.8	0.2	40.9	52.5	0.1	0.0	2.4	0.1	0.5	0.1	2.6	0.0	100.0
Crucible	IF0072	In body	0.7	0.2	26.1	68.3	0.0	0.2	2.7	0.2	0.1	0.0	1.5	0.0	100.0
Crucible	IF0073	In body 1	1.5	0.1	33.7	58.0	0.0	0.1	3.8	0.1	0.3	0.1	2.4	0.0	100.0
Crucible		In body 2	1.0	0.1	32.4	60.1	0.0	0.2	3.4	0.1	0.3	0.0	2.4	0.0	100.0
Crucible	IF0074	In body 1	0.5	0.2	33.5	60.3	0.0	0.1	3.4	0.2	0.1	0.0	1.7	0.0	100.0
Crucible		In body 2	0.5	0.2	35.4	58.8	0.0	0.1	2.6	0.2	0.3	0.0	1.9	0.0	100.0
Crucible	IF0075	In body 1	0.6	0.1	30.8	60.7	0.2	0.0	4.6	0.1	0.2	0.0	2.9	0.0	100.0
Crucible		In body 2	0.7	0.1	26.5	63.8	0.0	0.2	4.4	0.2	0.4	0.1	3.6	0.0	100.0
Crucible	IF0076	In body 1	0.8	0.2	28.3	65.2	0.0	0.2	2.7	0.1	0.6	0.0	1.9	0.0	100.0
Crucible		In body 2	0.8	0.1	26.7	67.3	0.0	0.2	2.6	0.1	0.3	0.0	2.0	0.0	100.0
Crucible	IF0077	In body 1	0.4	0.2	34.3	58.0	0.2	0.2	3.6	0.0	0.1	0.0	2.9	0.0	100.0
Crucible		In body 2	0.4	0.2	35.8	56.4	0.3	0.3	3.4	0.1	0.2	0.0	3.0	0.0	100.0
Crucible	IF0078	In body	0.3	0.1	35.1	59.6	0.0	0.3	3.0	0.1	0.2	0.0	1.4	0.0	100.0
Crucible	IF0079	In body	0.9	0.1	27.8	63.8	0.0	0.1	4.8	0.7	0.2	0.1	1.6	0.0	100.0
Crucible	IFCC 1	In body trans	1.6	0.4	33.3	56.9	0.0	0.1	4.6	0.2	0.2	0.1	2.6	0.0	100.0
Crucible	IF CC4	In body trans 1	2.7	0.2	35.4	55.6	0.1	0.0	2.9	0.3	0.5	0.0	2.1	0.0	99.9
Crucible		In body trans 2	2.5	0.2	39.8	52.7	0.2	0.1	2.5	0.4	0.5	0.0	1.2	0.0	99.9
Crucible	IF0072	In body trans	1.8	0.2	38.6	54.0	0.1	0.2	3.6	0.2	0.1	0.1	1.3	0.0	100.0
Crucible	IF0073	In body trans	1.8	0.0	36.9	54.3	0.0	0.1	4.0	0.2	0.2	0.2	2.4	0.0	100.0
Crucible	IF0074	In body trans	1.4	0.2	36.6	57.0	0.1	0.1	2.7	0.2	0.2	0.0	1.6	0.0	100.0
Crucible	IF0075	In body trans	2.3	0.1	32.2	59.5	0.0	0.1	2.8	0.2	0.3	0.0	2.4	0.0	100.0
Crucible	IF0076	In body trans	4.5	0.0	33.0	55.9	0.0	0.1	4.7	1.2	0.1	0.1	0.5	0.0	100.0
Crucible	IF0077	In body trans 1	0.9	0.1	40.1	52.1	0.3	0.2	2.4	0.1	0.2	0.0	3.7	0.0	100.0
Crucible		in body trans2	1.4	0.1	33.6	58.7	0.4	0.1	2.8	0.1	0.2	0.0	2.7	0.0	100.0

Appendix E. 7 (Cont.): Chemical composition of all the areas and spots analyzed in the crucible by SEM-EDS

Material	**Sample #**	**Area analyzed**	**Na2O**	**MgO**	**Al2O3**	**SiO2**	**P2O5**	**Cl**	**K2O**	**CaO**	**TiO2**	**MnO**	**FeO**	**CuO**	**Total**
Crucible	IF0078	In body trans	2.0	0.1	40.8	51.3	0.0	0.2	4.4	0.3	0.0	0.1	0.8	0.0	100.0
Crucible	IF0079	In body trans	1.3	0.1	35.2	55.5	0.1	0.1	5.5	0.4	0.3	0.0	1.6	0.0	100.0
Crucible	IFCC 1	In glass trans	3.6	0.1	20.8	59.7	0.1	0.0	6.9	7.0	0.1	0.4	1.4	0.0	100.0
Crucible	IF CC4	In glass trans 1	5.2	0.1	15.0	61.8	0.1	0.0	2.6	13.5	0.1	0.4	1.3	0.0	100.0
Crucible		In glass trans 2	6.5	0.1	24.8	58.8	0.3	0.0	3.8	4.5	0.2	0.0	1.0	0.0	100.0
Crucible	IF0072	In glass trans	4.3	0.2	19.2	67.2	0.2	0.1	6.9	0.5	0.0	0.1	1.4	0.0	100.0
Crucible	IF0073	In glass trans	4.6	0.1	23.0	58.0	0.2	0.1	6.5	4.7	0.5	0.2	2.2	0.0	100.0
Crucible	IF0074	In glass trans	4.3	0.1	16.7	62.8	0.2	0.0	4.1	10.8	0.0	0.4	0.6	0.0	100.0
Crucible	IF0075	In glass trans	4.8	0.0	14.3	65.9	0.2	0.0	2.8	10.0	0.2	0.7	1.1	0.0	100.0
Crucible	IF0076	In glass trans	4.2	0.0	13.1	66.0	0.2	0.0	3.6	11.3	0.1	0.9	0.6	0.0	100.0
Crucible	IF0077	In glass trans 1	8.1	0.5	17.9	61.9	0.3	0.2	7.1	1.1	0.2	0.6	1.9	0.4	100.0
Crucible		In glass trans 2	8.7	0.7	16.4	61.7	0.7	0.3	6.7	1.6	0.1	0.9	1.9	0.5	100.0
Crucible	IF0078	In glass trans	5.1	0.1	34.7	51.4	0.0	0.0	5.5	2.6	0.0	0.0	0.6	0.0	100.0
Crucible	IFCC 1	In glass 1	2.9	0.1	13.1	61.2	0.1	0.0	4.4	16.4	0.1	1.0	0.8	0.0	100.0
Crucible		In glass 2	3.0	0.0	13.0	61.0	0.0	0.0	4.2	17.0	0.1	0.9	0.8	0.0	100.0
Crucible	IF CC4	In glass 1	6.2	0.1	12.5	64.7	0.1	0.0	1.0	14.4	0.0	0.1	1.1	0.0	100.0
Crucible		In glass 2	6.1	0.0	12.4	63.4	0.1	0.0	1.0	15.6	0.0	0.2	1.2	0.0	100.0
Crucible	IF0072	In glass 1	5.1	0.9	16.5	64.7	0.4	0.2	6.2	2.1	0.1	0.1	3.7	0.0	100.0
Crucible		In glass black?	4.5	1.7	10.8	67.9	0.4	0.2	5.6	2.7	0.2	0.0	5.8	0.3	100.0
Crucible		In glass red?	4.4	1.6	10.2	67.1	0.4	0.1	5.3	4.5	0.2	0.1	5.9	0.3	100.0
Crucible	IF0073	In Glass	3.6	0.1	14.5	64.0	0.0	0.0	5.3	10.1	0.1	0.6	1.7	0.0	100.0
Crucible	IF0074	In glass 1	3.9	0.1	13.8	64.1	0.0	0.0	3.7	13.1	0.0	0.7	0.5	0.0	100.0
Crucible		In glass 2	3.9	0.1	13.7	62.6	0.2	0.0	3.9	14.5	0.1	0.7	0.4	0.0	100.0
Crucible	IF0075	In glass 1	4.8	0.1	11.4	67.2	0.2	0.0	1.4	13.7	0.1	0.8	0.4	0.0	100.0
Crucible		In glass 2	4.7	0.0	26.7	55.5	0.1	0.0	1.8	10.1	0.3	0.1	0.7	0.0	100.0
Crucible		In glass 3	4.6	0.0	33.8	54.1	0.0	0.0	3.5	2.5	0.5	0.1	1.0	0.0	100.0

Appendix E. 7 (Cont.): Chemical composition of all the areas and spots analyzed in the crucible by SEM-EDS

Material	Sample #	Area analyzed	Na2O	MgO	Al2O3	SiO2	P2O5	Cl	K2O	CaO	TiO2	MnO	FeO	CuO	Total
Crucible	IF0076	In glass 1	4.1	0.1	12.3	63.0	0.1	0.0	3.3	15.9	0.1	0.8	0.4	0.0	100.0
Crucible		In glass 2	4.1	0.2	14.6	66.7	0.2	0.0	3.8	8.5	0.0	1.4	0.6	0.0	100.0
Crucible		In glass 3	4.4	0.1	13.7	65.5	0.1	0.0	3.9	10.9	0.1	0.5	0.7	0.0	100.0
Crucible	IF0077	In glass 1	8.2	1.1	12.3	65.2	0.4	0.4	6.6	2.4	0.1	1.3	1.4	0.7	100.0
Crucible		In glass 2	8.1	1.1	12.2	65.2	0.5	0.4	6.2	2.5	0.2	1.3	1.6	0.8	100.0
Crucible	IF0078	In glass 1	4.5	0.0	15.6	63.2	0.0	0.0	4.9	11.0	0.1	0.0	0.7	0.0	100.0
Crucible		In glass 2	4.3	0.1	16.7	67.5	0.7	0.1	5.6	4.4	0.0	0.1	0.7	0.0	100.0
Crucible	IF0079	In glass 1	1.8	0.1	12.5	65.3	0.1	0.0	5.2	12.8	0.1	1.0	1.1	0.0	100.0
Crucible		In glass 2	1.9	0.1	14.3	62.0	0.2	0.0	5.2	14.0	0.2	1.2	1.0	0.0	100.0

Appendix E. 8: Chemical composition of all the areas and spots analyzed in the corroded beads and droplets by SEM-EDS

Material	Sample #	Area analyzed	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	Cl	K_2O	CaO	TiO_2	MnO	FeO	CuO	Total
Beads (Corroded)	IF0083A	area 1	1.8	0.0	14.0	60.3	0.2	0.0	9.1	13.8	0.1	0.4	0.3	0.0	100.0
Beads (Corroded)		area 2	1.9	0.0	14.0	60.4	0.2	0.0	9.1	13.6	0.1	0.4	0.3	0.0	100.0
Beads (Corroded)	IF0083B	area 1	3.6	0.1	16.3	62.8	1.4	0.0	2.9	12.0	0.1	0.1	0.8	0.0	100.0
Beads (Corroded)		area 2	3.6	0.1	17.0	63.7	1.5	0.0	3.1	9.8	0.2	0.1	1.0	0.0	100.0
Beads (Corroded)		area 3	3.3	0.1	13.5	62.1	0.0	0.0	2.3	18.0	0.1	0.1	0.6	0.0	100.0
Beads (Corroded)	IF0084	Area 1	2.0	0.0	12.7	60.9	0.1	0.0	7.9	15.7	0.1	0.3	0.4	0.0	100.0
Beads (Corroded)		Area 2	2.0	0.0	12.7	61.3	0.1	0.0	8.0	15.3	0.0	0.3	0.3	0.0	100.0
Droplets (Corroded)	IF0085	area1	0.1	3.8	15.9	42.1	2.5	0.0	0.5	32.4	1.2	0.3	1.2	0.0	100.0
Droplets (Corroded)		area 2	0.1	4.5	15.3	41.6	3.1	0.0	0.5	32.8	1.2	0.3	0.7	0.0	100.0
Droplets (Corroded)		area 3	0.0	3.2	16.7	43.1	2.5		0.5	31.7	1.2	0.4	0.8	0.0	100.0
Droplets (Corroded)	IF0085	area 1	0.2	3.3	16.1	42.0	1.5	0.0	7.3	27.9	0.4	0.2	1.2	0.0	100.0
Droplets (Corroded)		area 2	0.3	3.1	16.2	42.7	1.4	0.0	7.7	26.7	0.4	0.2	1.4	0.0	100.0
Droplets	IF0085	area 1	0.4	3.6	12.6	51.0	1.0	0.0	8.1	21.3	0.5	0.3	1.2	0.0	100.0
Droplets		area 2	0.4	3.7	12.1	52.5	0.7	0.0	7.5	21.3	0.5	0.4	0.9	0.0	100.0

Appendix E. 9: Chemical composition of all the areas and spots analyzed in the vitrified production debris (VPD) by SEM-EDS

Material	**Sample #**	**Area analyzed**	**Na_2O**	**MgO**	**Al_2O_3**	**SiO_2**	**P_2O_5**	**Cl**	**K_2O**	**CaO**	**TiO_2**	**MnO**	**FeO**	**CuO**	**Total**
VPD	IF0093	White Area 1	0.2	1.8	12.3	59.4	1.1	0.0	6.0	6.2	3.1	0.2	9.7	0.0	100.0
VPD		White area 2	0.3	1.0	12.9	66.0	0.5	0.0	7.6	3.2	2.7	0.1	5.7	0.0	100.0
VPD		White needle xtals 1	0.4	0.9	19.4	46.4	0.3	0.0	1.5	1.0	8.2	0.3	21.6	0.0	100.0
VPD		White needle xtals 2	0.1	0.6	9.2	24.2	0.5	0.0	0.6	0.6	28.9	0.4	34.8	0.0	100.0
VPD		White xtals 1	0.2	0.9	9.9	25.1	0.2	0.0	0.6	0.9	28.0	0.4	33.7	0.0	100.0
VPD		White xtals 2	0.1	0.6	13.6	32.2	0.3	0.0	0.3	0.2	15.9	0.2	36.6	0.0	100.0
VPD		White xtals 3	0.1	0.9	12.3	21.4	0.2	0.0	0.6	0.5	28.0	0.5	35.5	0.0	100.0
VPD	IF0094	White area bulk	0.1	1.2	4.6	80.1	0.5	0.0	3.1	4.7	2.2	0.1	3.2	0.0	100.0
VPD		White area 1	0.0	1.5	6.5	73.6	0.8	0.0	4.3	6.2	3.0	0.1	4.0	0.0	100.0
VPD		White area 2	0.1	1.5	7.7	66.4	0.7	0.0	5.1	5.9	4.1	0.3	8.2	0.0	100.0
VPD		White needle xtals	0.0	1.1	13.7	1.8	0.0	0.0	0.1	0.2	55.3	0.1	27.0	0.0	99.3
VPD	IF0095	White spots 1	0.0	0.0	0.1	0.1	13.9	0.0	0.0	0.1	0.1	0.0	83.4	0.0	97.7
VPD		White spots 2	0.1	1.4	11.4	38.3	1.6	0.0	1.9	2.5	2.0	0.3	40.5	0.0	100.0
VPD		White spots 3	0.2	2.1	16.6	57.2	0.3	0.0	2.9	4.7	3.7	0.5	11.9	0.0	99.9
VPD		White spots 4	0.0	0.0	0.0	0.2	16.2	0.0	0.0	0.1	0.2	0.0	81.8	0.0	98.5
VPD	IF0096	White area 1	0.3	3.6	3.4	63.8	1.4	0.0	7.8	15.1	1.9	0.3	2.3	0.0	100.0
VPD		White area 2	0.2	2.3	3.5	73.5	1.0	0.0	6.1	8.3	2.0	0.2	2.9	0.0	100.0
VPD		White xtals 1	0.0	0.3	2.3	3.5	0.0	0.0	0.1	0.1	47.1	0.5	44.5	0.0	98.6
VPD		White xtals 2	0.1	0.4	2.3	7.0	0.4	0.0	0.2	0.1	46.0	0.5	43.0	0.0	100.0
VPD		Gray xtals	0.1	1.0	45.6	9.6	0.2	0.0	0.2	0.0	4.5	0.2	38.4	0.0	99.7
VPD	IF0097	White area 1	0.1	1.3	7.9	64.4	1.2	0.0	6.3	5.2	3.1	0.3	10.2	0.0	100.0
VPD		White area 2	0.2	1.7	7.2	64.2	1.3	0.0	6.9	7.2	3.1	0.4	7.8	0.0	100.0
VPD		White area 3	0.1	0.7	3.4	81.4	0.6	0.0	3.2	5.2	3.1	0.1	2.5	0.0	100.0
VPD	IF0093	black area 1	0.1	0.4	16.7	62.9	0.4	0.0	0.3	0.4	4.8	0.2	13.8	0.0	100.0

Appendix E. 9 (Cont.): Chemical composition of all the areas and spots analyzed in the vitrified production debris (VPD) by SEM-EDS

Material	**Sample #**	**Area analyzed**	**Na2O**	**MgO**	**Al2O3**	**SiO2**	**P2O5**	**Cl**	**K2O**	**CaO**	**TiO2**	**MnO**	**FeO**	**CuO**	**Total**
VPD		Black area 2	0.1	0.3	15.3	66.9	0.4	0.0	0.3	0.4	4.4	0.2	11.7	0.0	100.0
VPD		Black area 3	0.1	0.2	14.2	70.4	0.3	0.0	0.3	0.3	3.9	0.1	10.3	0.0	100.0
VPD		Black area 4	0.1	0.3	15.7	67.7	0.4	0.0	0.4	0.4	4.2	0.1	10.8	0.0	100.0
VPD	IF0094	Black area bulk	0.1	0.7	6.5	79.4	0.3	0.0	1.2	3.0	3.1	0.1	5.6	0.0	100.0
VPD		Black area 1	0.2	1.0	11.6	66.9	0.6	0.0	1.0	3.3	4.6	0.3	10.7	0.0	100.0
VPD		Black area 2	0.1	1.2	10.4	68.1	0.5	0.0	2.1	4.6	4.5	0.0	8.5	0.0	100.0
VPD	IF0095	Black area 1	0.1	1.1	12.9	66.2	0.4	0.0	3.9	3.4	2.8	0.3	8.8	0.0	100.0
VPD		Black area 2	0.2	0.6	11.7	69.5	0.4	0.0	2.8	2.3	2.6	0.2	9.8	0.0	100.0
VPD		Black area 3	0.2	1.3	17.3	56.2	0.5	0.0	4.0	3.9	3.8	0.3	12.4	0.0	99.9
VPD		Black area 4	0.2	1.0	16.2	58.4	0.5	0.0	3.1	3.0	3.6	0.3	13.7	0.0	100.0
VPD	IF0096	Black area 1	0.1	0.1	7.5	74.3	0.2	0.0	0.2	0.2	5.4	0.1	11.8	0.0	99.9
VPD		Black area 2	0.0	0.3	7.5	76.8	0.2	0.0	0.3	0.1	5.7	0.2	8.9	0.0	100.0
VPD		Black area 3	0.1	0.3	8.8	72.7	0.1	0.0	0.3	0.2	6.3	0.2	10.9	0.0	100.0
VPD	IF0097	Black area 1	0.2	0.2	12.5	67.0	0.3	0.0	0.4	0.5	5.1	0.2	13.6	0.0	100.0
VPD		Black area 2	0.3	0.5	16.9	56.2	0.6	0.0	0.6	0.7	8.9	0.4	14.9	0.0	100.0
VPD		Black area 3	0.0	0.3	14.3	67.5	0.4	0.0	0.4	0.8	6.9	0.1	9.4	0.0	100.0

Appendix E. 10: Chemical composition of all the areas and spots analyzed in the ceramic cylinders by SEM-EDS

Material	Sample #	Area analyzed	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	Cl	K_2O	CaO	TiO_2	MnO	FeO	CuO	Total
Ceramic cylinders	IF0080	Out glaze 1	1.1	3.0	11.8	43.2	9.8	0.0	3.0	21.0	2.1	0.3	5.0	0.0	100.0
Ceramic cylinders		Out glaze 2	0.4	1.4	11.9	48.8	3.0	0.0	3.5	17.2	1.7	0.2	11.9	0.0	100.0
Ceramic cylinders		Out glaze 3	0.8	1.6	12.7	51.6	2.9		4.6	16.1	1.5		8.2	0.0	100.0
Ceramic cylinders	IF0082	Out Glaze	0.5	2.2	13.1	48.6	4.2	0.0	2.8	18.5	2.4	0.3	7.4	0.0	100.0
Ceramic cylinders	IF0080	Red fabric bulk	1.0	2.0	21.4	60.5	0.1	0.3	0.6	2.0	1.0	0.1	10.9	0.0	100.0
Ceramic cylinders		Red fabric 1	1.1	1.9	19.4	63.1	0.0	0.3	0.5	2.0	1.6	0.1	10.2	0.0	100.0
Ceramic cylinders		Red fabric 2	1.4	1.9	22.8	59.7	0.1	0.3	0.6	2.3	0.7	0.0	10.4	0.0	100.0
Ceramic cylinders		Red fabric 3	1.3	1.8	24.8	56.6	0.1	0.3	1.4	3.7	0.8	0.1	9.3	0.0	100.0
Ceramic cylinders		Red fabric 4	1.0	2.2	23.4	57.8	0.2	0.3	1.3	2.5	0.9	0.1	10.3	0.0	100.0
Ceramic cylinders	IF0081	Red fabric 1	0.3	0.5	17.1	65.1	2.8	0.0	0.5	1.3	2.9	0.1	9.5	0.0	100.0
Ceramic cylinders		Red fabric 2	0.3	0.4	17.0	66.0	1.9	0.1	0.5	0.8	3.1	0.4	9.4	0.0	100.0
Ceramic cylinders	IF0080	Black fabric 1	1.5	1.4	21.9	56.5	0.3	0.0	6.0	3.9	0.6	0.1	7.8	0.0	100.0
Ceramic cylinders		Black fabric 2	1.3	1.6	20.4	57.8	0.2	0.1	5.8	3.2	0.5	0.1	9.1	0.0	100.0
Ceramic cylinders	IF0082	Black Fabric 1	0.9	1.9	15.7	66.8	0.0	0.3	0.2	2.5	2.6	0.1	9.0	0.0	100.0
Ceramic cylinders		Black Fabric 2	0.3	2.2	19.0	59.2	0.3	0.0	3.7	3.1	2.8	0.1	9.5	0.0	100.0
Ceramic cylinders	IF0081	Gray fabric 1	0.6	0.5	17.5	65.4	2.3	0.1	0.4	1.5	2.9	0.2	8.7	0.0	100.0
Ceramic cylinders		Gray fabric 2	0.4	0.5	14.0	71.3	2.0	0.2	0.4	1.0	2.5	0.2	7.7	0.0	100.0

Appendix E. 11: Chemical composition of all the areas and spots analyzed in the domestic pottery by SEM-EDS

Material	Sample #	Area analyzed	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	Cl	K_2O	CaO	TiO_2	MnO	FeO	CuO	Total
Domestic pottery	IF0086	Fabric 1	0.5	0.6	13.4	72.9	2.0	0.2	0.6	1.4	2.0	0.1	6.3	0.0	100.0
Domestic pottery		Fabric 2	0.3	0.5	13.1	73.9	1.8	0.2	0.4	1.1	2.0	0.0	6.6	0.0	100.0
Domestic pottery		Fabric 3	0.4	0.6	13.2	73.0	2.0	0.2	0.7	1.3	1.9	0.1	6.7	0.0	100.0
Domestic pottery	IF0087	Fabric 1	1.6	1.3	23.7	54.4	1.4	0.1	3.4	1.7	1.6	0.0	10.7	0.0	100.0
Domestic pottery		Fabric 2	1.9	1.3	23.5	55.6	1.1	0.1	3.4	1.9	1.4	0.1	9.9	0.0	100.0
Domestic pottery	IF0088	Fabric 1	2.8	2.7	21.1	56.1	1.4	0.1	1.2	3.6	1.4	0.1	9.6	0.0	100.0
Domestic pottery		Fabric 2	2.5	2.8	21.1	56.6	1.1	0.1	1.9	3.5	1.2	0.1	9.1	0.0	100.0
Domestic pottery	IF0089	Fabric 1	2.4	1.7	25.3	62.5	1.5	0.1	0.2	1.6	0.6	0.0	4.1	0.0	100.0
Domestic pottery		Fabric 2	2.1	1.8	25.9	61.8	1.4	0.1	0.1	1.5	0.7	0.0	4.6	0.0	100.0
Domestic pottery	IF0090	Fabric 1	1.4	2.6	17.8	64.8	1.8	0.2	0.6	3.2	1.3	0.0	6.3	0.0	100.0
Domestic pottery		Fabric 2	1.5	2.8	18.4	64.3	1.5	0.2	0.6	3.2	1.4	0.1	6.1	0.0	100.0
Domestic pottery	IF0091	fabric 1	1.6	2.2	22.2	56.0	0.9	0.1	1.5	2.8	1.4	0.1	11.3	0.0	100.0
Domestic pottery		Fabric 2	1.5	2.3	22.6	55.3	0.9	0.1	1.4	3.2	1.3	0.2	11.4	0.0	100.0
Domestic pottery	IF0092	Fabric 1	2.5	1.6	18.5	62.8	0.1	0.3	1.9	3.3	1.0	0.1	8.0	0.0	100.0
Domestic pottery		Fabric 2	2.9	1.3	18.5	64.2	0.1	0.2	2.3	3.0	1.0	0.0	6.6	0.0	100.0